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Influence of gyroscopic action on the necessary superelevation to be provided on curves,

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Figs. 1 to 7, pp. 492 to 500.

I. — Introduction.

The superelevation of the outside rail on curves is so calculated that the horizontal component of the weight of a vehicle passing round the curve at any given speed shall be equal to the centrifugal force acting on the vehicle.

On this basis the superelevation h , in metres, is given by an equation ⁽¹⁾:

$$h = \frac{s}{g} \cdot \frac{V^2}{R} \dots \dots (1)$$

in which :

s , is the gauge, in metres;

g , the acceleration due to gravity, in metres per second per second;

V , the speed, in metres per second;

R , the radius of the curve, in metres.

As in practice, provision must be made for the various speeds at which trains pass round the curve, the formula (1) has to be modified, and for the majority

of speeds it is not possible to completely balance the centrifugal force.

The Italian State Railways use, in order to determine the superelevation of the outside rail, the above formula (1), giving V the value given by

$$V^2 = \frac{V_1^2 + V_2^2}{2} \dots \dots (2)$$

where V_1 is the maximum speed and V_2 the minimum speed of trains running on the line.

With this value of V , the resultant of the weight and the centrifugal force approximately bisects the angle formed by the two similar resultants corresponding to the maximum speed and the minimum speed.

The formulæ given above are satisfactory in practice when the maximum speed does not exceed the ordinary figure, that is to say, 120 to 140 km. (75 to 87 miles) per hour.

The present day tendency to higher

⁽¹⁾ See CORINI: *Lezioni di Ferrovie*, vol. I, p. 193. — Publishers Donati Bros., Parma, 1925.

speeds makes it necessary for us to investigate whether, in the event of higher speeds being adopted, it would be necessary, in determining the superelevation, to take into account other factors besides the effects of centrifugal force.

We may refer to the trials carried out in Germany, between Berlin and Zossen, with trains running at 200 km. (124.3 miles) per hour. An investigation of

the problem which we have just raised may find its justification in such tests which have already had an effect upon the speeds attained in every day practice.

II. — Gyroscopic action as affecting railway rolling stock.

Considering (fig. 1) a system of three co-ordinates Ox , Oy , Oz , and a cylinder whose axis $O\xi$ coincides with the co-

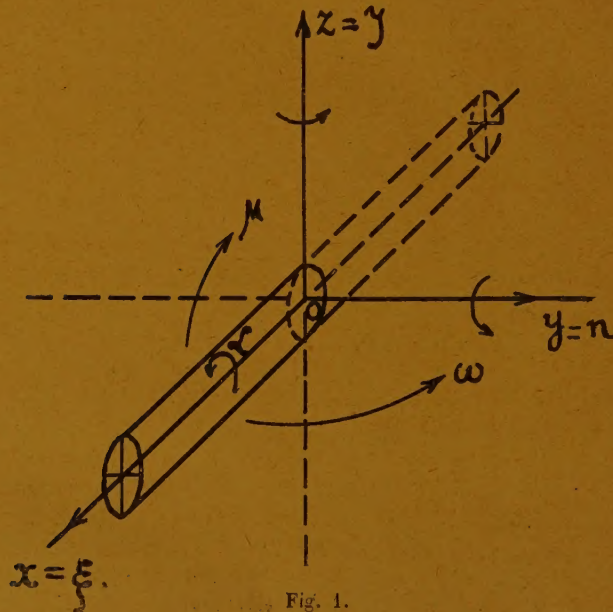


Fig. 1.

ordinate Ox . Suppose that initially the cylinder rotates round its geometrical axis which remains fixed with a positive angular velocity $\alpha = 2\pi n$, where n is the number of revolutions per second. Let us now suppose that the axis $O\xi$ turns in space around the point O with an angular velocity ω whose components along the three co-ordinates are ω_x , ω_y , ω_z .

In order to investigate the dynamic equilibrium of the system at any given

instant, let us take as co-ordinates Ox , Oy , Oz , the principal axes of inertia of the cylinder, and apply Euler's equations dealing with the motion of a body around a point, namely :

$$(3) \quad \begin{cases} I_x \frac{d\omega_x}{dt} + (I_z - I_y) \cdot \omega_z \cdot \omega_y = M'_x \\ I_y \frac{d\omega_y}{dt} + (I_x - I_z) \cdot \omega_x \cdot \omega_z = M'_y \\ I_z \frac{d\omega_z}{dt} + (I_y - I_x) \cdot \omega_y \cdot \omega_x = M'_z \end{cases}$$

in which I_x, I_y, I_z are the moments of inertia of the cylinder with respect to the three axes; M'_x, M'_y, M'_z are the moments of the applied forces with respect to the same axes. In the case of the cylinder $I_z = I_y$ and consequently the second term of the first equation (3) disappears.

To take into account, not only the rotation ω around the point O, but also the rotation of the cylinder around its own

axis $O\xi$ (relative motion), we should take M'_x, M'_y, M'_z as the sum of the moments of the applied forces and of the inertia forces due to the relative motion. These are of two orders: the inertia force corresponding to the acceleration of relative motion, and the inertia force corresponding to the centrifugal acceleration determined by Coriolis. By introducing the values of this inertia force in the equations (3), we obtain:

$$(4) \quad \left\{ \begin{array}{l} I_x \cdot \frac{d\omega_x}{dt} = M_x \\ I_y \cdot \frac{d\omega_y}{dt} + (I_x - I_z) \omega_x \omega_z = M_y + \omega_z \alpha I_x \\ I_z \cdot \frac{d\omega_z}{dt} + (I_y - I_x) \omega_y \omega_x = M_z - \omega_y \alpha I_x \end{array} \right.$$

Suppose now that:

$$\begin{aligned} \omega_x &= \omega_y = 0 \\ \omega_z &= \omega = \text{constant} \end{aligned}$$

in other words, supposing that while the cylinder rotates about its axis with a velocity α , the motion of its axis is reduced to a rotation around the co-ordinate z , that is to say that $O\xi$ remains in the plane xy at a constant velocity ω .

Equations (4) then reduce to the following:

$$(5) \quad \left\{ \begin{array}{l} M_x = 0 \\ M_y = -I_x \cdot \omega \cdot \alpha \\ M_z = 0. \end{array} \right.$$

Supposing on the other hand that we have:

$$\omega_x = \omega_z = 0$$

and

$$\omega_y = \omega = \text{constant}$$

in other words, supposing that the axis $O\xi$ moves in the plane xz by turning

about point O (or about the co-ordinate y) with a constant velocity ω . Then the equations (4) reduce to the following:

$$(6) \quad \left\{ \begin{array}{l} M_x = 0 \\ M_y = 0 \\ M_z = I_x \cdot \omega \cdot \alpha. \end{array} \right.$$

Equations (5) and (6) are the formulæ given by Foucault, who first investigated this problem. The interpretation of equations (5) is as follows: if, to a cylinder turning about the axis Ox with a positive angular velocity α , is applied an external couple defined by:

$$\begin{aligned} M_x &= 0 \\ M_y &= -\mu \\ M_z &= 0 \end{aligned}$$

the axis of the cylinder turns in the plane xy with an angular velocity ω given by:

$$\omega = \frac{-\mu}{-I_x \cdot \alpha} = \frac{\mu}{I_x \cdot \alpha}.$$

Conversely, if a cylinder turning about the axis Ox with a positive angular velo-

city z , is constrained to turn with its axis $O\xi$ in the plane xy around the point O , with a positive angular velocity ω , it must be acted upon by a couple given by :

$$M_x = 0$$

$$M_y = \mu$$

$$M_z = 0$$

or

$$\mu = -I_x \cdot \omega \cdot \alpha.$$

The meaning of equations (6) is similar : the cylinder is acted upon by a positive couple in the plane xy , the axis $O\xi$ turns around O (or the co-ordinate y) remaining in the plane xz in a positive direction. If the cylinder is

made to turn in the plane xz in a positive direction, it is acted upon by a positive couple acting in the plane xy . The results obtained are the same as those which would be obtained by considering, instead of a cylinder, a solid of revolution around axis $O\xi$. One can easily verify how the equations (5) explain the behaviour of a top.

III. — Gyroscopic action with passing round a curve.

Consider now a pair of wheels and axles passing round a curve of radius R . At any given instant, let us refer the motion to the axes Ox, Oy, Oz (fig. 2). The axle passes from position AB to

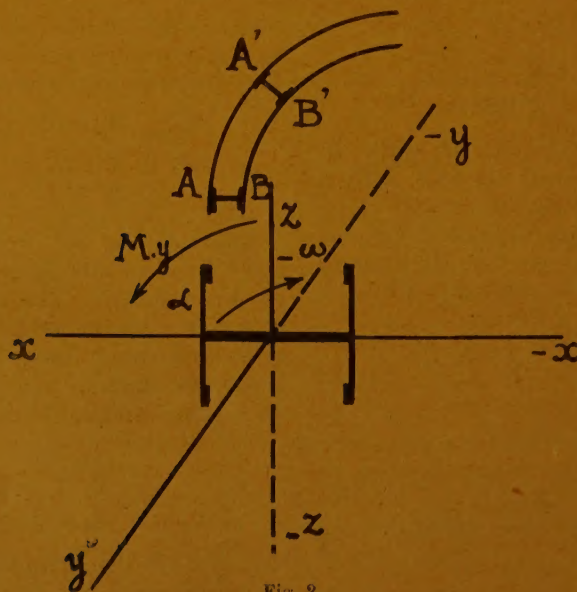


Fig. 2.

position $A'B'$ by a negative rotation ω about z , a negative translational movement about y and a negative translational movement about x .

The translational movements have no

effect on the gyroscopic action which we are here considering. We can therefore omit any consideration of the translational movements and confine our attention to the rotation $-\omega$.

The value of this angular velocity is obviously given by :

$$-\omega = -\frac{V}{R}$$

where V is the speed, in metres per second, at which the axle is travelling along the line, and R the radius of the curve, in metres. The axle is therefore turning around its own axis with positive angular velocity given by :

$$\alpha = \frac{V}{r}$$

where r is the radius of the wheel.

Substituting these values in equation (5), it becomes :

$$M_y = -I_x \cdot \frac{V}{r} \cdot \left(-\frac{V}{R}\right) = I_x \cdot \frac{V^2}{r \cdot R} \quad (7)$$

which is equivalent to saying that a *positive gyroscopic movement is set up in the plane xz* .

If we denote by p the weight of the axle, we can write :

$$I_x = \frac{p}{g} \cdot \rho^2$$

where g is the acceleration due to gravity and ρ is the radius of gyration of the axle; by substituting these in (7), we have :

$$M_y = \frac{p}{g} \cdot \frac{\rho^2}{R \cdot r} \cdot V^2 \dots \dots (8)$$

If we consider the case of a steam locomotive with n axles whose weight is $p_1, p_2 \dots p_n$, and of which the radius of the wheels is $r_1, r_2 \dots r_n$ and the radii of gyration are $\rho_1, \rho_2 \dots \rho_n$, we find that the total gyroscopic moment in a vertical plane is given by :

$$M_y = \frac{V^2}{gR} \sum_1^n \frac{p_n \rho_n^2}{r_n} \dots \dots (9)$$

Let H be the normal distance of the centre of gravity of the locomotive above the rails.

We can represent the moment M by two parallel forces, one of which is applied at the centre of gravity parallel to the plane of the track, and the other at the rim of the wheel in the plane of the track.

Each of these forces has the value :

$$\varphi = \frac{1}{H} \cdot M_y \dots \dots (10)$$

If, instead of a steam locomotive we consider the case of an electric locomotive with m motors having weights $p'_1, p'_2 \dots p'_m$, and radii of gyration $\rho'_1, \rho'_2 \dots \rho'_m$, and designate by K the ratio between the angular velocity of the motors and the wheels, equations (9), (10) become :

$$M_y = \frac{V^2}{Rg} \left(\sum_1^n \frac{p_n \rho_n^2}{r_n} \pm K \sum_1^m \frac{p'_m \rho_m^2}{r_m} \right) \quad (9')$$

$$\varphi' = \frac{1}{H} \cdot M'_y \dots \dots (10')$$

The $+$ sign is used if the motors turn in the same direction as the wheels, and the $-$ sign if they turn in the opposite direction.

IV. — Gyroscopic moment due to a transition curve, the superelevation of the outer rail increasing gradually.

Consider now a pair of wheels and axle running round a transition curve, the inside rail of which is inclined downwards at a gradient of $-\frac{i}{2}$ and the outside rail inclined upwards at a gradient of $+\frac{i}{2}$; the inclination of the outer rail relative to the inner rail being therefore i .

If the n axles are all fixed, as regards the frame of a locomotive, and the rigid wheel base is l , the moments M_z and M'_z are represented (fig. 4) by two parallel

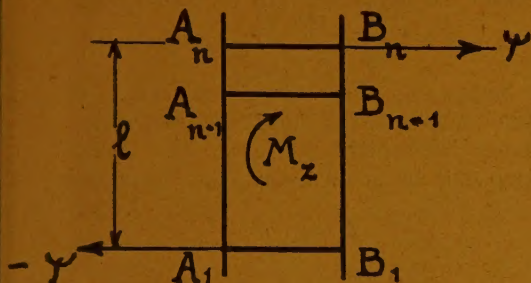


Fig. 4.

forces Ψ and $-\Psi$, one being applied at B_n and the other at A_1 , the directions being such as will cause the inside wheel of the leading axle to bear against the inside rail and the outside wheel of the trailing axle to bear against the outside rail.

The intensity of these forces is given by :

$$\Psi = \frac{1}{l} M_z \dots \dots \dots (13)$$

$$\Psi' = \frac{1}{l} M'_z \dots \dots \dots (13')$$

If the locomotive is provided with bogies or radial trucks, one should apply the above formulæ to each group of rigid axles, and take into account the centre pins through which they transmit forces analogous to Ψ .

Radii of the coupled wheels (r_1) = 1 m. (3 ft. 3 3/8 in.).
 Radii of the leading bogie (r_2) = 0 m. 48 (1 ft. 6 7/8 in.).
 Radii of the trailing axle wheel (r_3) = 0 m. 68 (2 ft. 2 3/4 in.).

V. — Superelevation of the outside rail.

The ratio between the force φ in the formula (10) arising from the gyroscopic moment in the plane xy , and the centrifugal force is given by :

$$\varepsilon = \frac{\frac{1}{H} M_y}{\frac{P}{g} \frac{V^2}{R}}$$

or

$$\varepsilon = \frac{\sum_1^n \frac{p_n \varphi_n^2}{r_n}}{H \cdot P} \dots \dots \dots (14)$$

for a steam locomotive, and by

$$\varepsilon' = \frac{\sum_1^n \frac{p_n \varphi_n^2}{r_n} \pm K \sum_1^m \frac{p_m \varphi_m^2}{r_m}}{H \cdot P} \dots \dots \dots (14')$$

for an electric locomotive.

Let us apply formula (14) to a locomotive of the 4-6-2 *Pacific* type having the following characteristics :

Total weight (P) = 93 000 kgr. (205 030 lb.).

Weights of wheels and axles :

Leading bogie . . . 3 000 kgr. (6 610 lb.)

Three coupled
 axles. 13 500 kgr. (29 760 lb.)

Trailing axle. . . . 2 500 kgr. (5 510 lb.)

Total. . . . 19 000 kgr. (41 880 lb.)

Height of the centre of gravity above the rail level.

$$(H) = 1.8 \text{ m. (5 ft. 10 } \frac{7}{8} \text{ in.)}$$

Generally speaking we can take

$$\rho = 0.70 r.$$

We find that :

$$\varepsilon = 5\%.$$

Let us apply formula (14') to an electric locomotive of a 2-8-2 type having the same weight as the steam locomotive dealt with above, the wheels and axles weighing 19 000 kgr. (41 880 lb.), that is 16 000 kgr. (35 270 lb.) for the four coupled axles with wheels 1 m. (3 ft. 3 $\frac{3}{8}$ in.) in radius, and 3 000 kgr. (6 610 lb.) for the two carrying axles having wheels 0.6 m. radius (1 ft. 11 $\frac{5}{8}$ in.). Let us assume that this locomotive is provided with two electric motors, the rotors of which together weigh 10 000 kgr. (22 000 lb.) and of which the radius of gyration is 0.25 m. (9 $\frac{13}{16}$ inches). Also let us assume that $K = 6$ and $H = 1.5$ m. (4 ft. 11 in.).

If the motors turn in the same direction as the wheels, we have :

$$\varepsilon' = 15.70\%.$$

* It will be seen that the force applied at the centre of gravity in the same direction as the centrifugal force due to gyroscopic action in the plane xz has a value which ranges from 5 to 16 % of the value of the centrifugal force; in other words, it is of sufficient importance to be taken into account.

Let us calculate M' in absolute units for the case of the electric locomotive mentioned above running at a speed of 200 km. (124.3 miles) per hour, that is about 55 m. (180 feet) per second, over a line which has curves of a minimum

radius of 1 000 m. (50 chains). By applying formula (9') we have :

$$M' = 4\,158 \text{ kgm. (30\,075 foot-pounds).}$$

In the case of the above mentioned steam locomotive, it will be found that :

$$M = 2\,741 \text{ kgm. (19\,819 foot-pounds).}$$

Supposing that the superelevation of the track is sufficient to completely balance the centrifugal force, the locomotive will be acted upon (fig. 5) on the

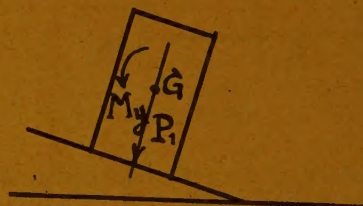


Fig. 5.

one hand by a force P_1 normally to the plane of the track and passing through the centre of gravity of the locomotive, and on the other hand, by the moment M'_y (or M_y). This system of forces is equivalent to a force P' parallel to P and at a distance from the latter δ given by :

$$\delta = \frac{M_y}{P_1}$$

In the case of the electric locomotive, $\delta = 5$ cm. (1 $\frac{31}{32}$ inches), and in the case of the steam locomotive, $\delta = 3.5$ cm. (1 $\frac{3}{8}$ inches). On the assumptions which we have made, the effect is not of very great importance. In practice, however, the outer rail is not given a sufficient superelevation to completely balance the centrifugal force, but as we have already said, the superelevation is calculated by means of formula (1) introducing the value V given by formula (2).

When the locomotive is running at a maximum speed V_1 , it is no longer acted upon (fig. 6) by the force P_1 , normally

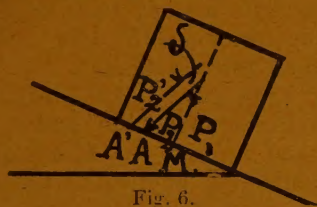


Fig. 6.

to the plane of the track, but by the force P_2 which meets the plane of the track at a point A, which is the point furthest distant from the axis M, which may be allowed from the point of view of the stability of the vehicle.

By combining the force P_2 with the moment M, we obtain a system equivalent to a force P'_2 parallel to P_2 and a distance from the latter δ . The force P'_2 meets the plane of the track at a point A', the distance of which from the point M exceeds the maximum distance A by the distance AA' which is a little greater

than δ . In this case, if δ is only a few centimetres in length, the effect becomes sufficiently important to reduce the stability of the vehicle, and if the point A is taken in its limiting position, the effect destroys the stability of the vehicle.

It will be seen therefore that it is necessary to take into account the gyroscopic action in determining the superelevation of the outside rail in cases where the curves are to be traversed by trains running at very high speeds.

Let us give to the plane of the track an inclination such that with the resultant of the forces parallel to the plane of the track it shall balance, not only the centrifugal force, but also the force φ or φ' given by formulæ (10) and (10'); we shall then have :

$$P \cdot \frac{h}{s} = \frac{P}{g} \frac{V^2}{R} + \frac{1}{gH} \sum \frac{p_n \varphi_n^2}{r_n} \cdot \frac{V^2}{R}$$

for lines worked by steam locomotives, and :

$$P \cdot \frac{h}{s} = \frac{P}{g} \frac{V^2}{R} + \frac{1}{gH} \frac{V^2}{R} \left(\sum_1^n \frac{p_n \varphi_n^2}{r_n} \pm K \sum_1^m \frac{p_m \varphi_m^2}{r_m} \right)$$

for lines worked by electric locomotives.

Therefore :

$$h = \beta \frac{s}{g} \frac{V^2}{R} \dots \dots \dots (15)$$

in which

$$\beta = 1 + \frac{\sum_1^n \frac{p_n \varphi_n^2}{r_n}}{H \cdot P} = 1 + \varepsilon \dots \dots \dots (16)$$

where ε is given by formula (14) for steam locomotives, and

$$\beta = 1 + \frac{\sum_1^n \frac{p_n \varphi_n^2}{r_n} \pm K \sum_1^m \frac{p_m \varphi_m^2}{r_m}}{H \cdot P} = 1 + \varepsilon' \dots \dots \dots (16')$$

where ε' is given by formula (14') for lines worked by electric locomotives.

As we have already seen above, the value of β ranges for high speeds from 1.05 to 1.16.

The superelevation thus given is equivalent to a force P_2 applied at the point A and a force $-\varphi$ situated in the plane of the track.

For all the speeds for which the line of action for the force P_2 is included in the angle NGA (fig. 7), the presence of the force $-\varphi$ is favourable to stability

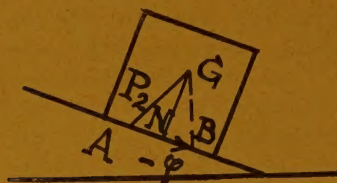


Fig. 7.

in that it opposes the transverse movement of the locomotive. For speeds at which the direction of the force P_2 is included in the angle NGB, the presence of the force $-\varphi$ assists the resultant of the force P_2 along the plane of the track to cause a transverse movement of the locomotive.

To summarise, an increase in the superelevation up to an amount sufficient to balance not only the centrifugal force corresponding to the speed V given by formula (2), but also the force φ , is necessary to guarantee stability against rotation about the outer rail; it decreases the tendency to move sideways at high speeds, but increases the tendency to move sideways at low speeds.

The conclusion is therefore that one should calculate the superelevation of the outer rail by means of formula (15), taking into account the values (16) and (16') of the gyroscopic coefficient β .

VI. — Maximum inclination of the outer rail on transition curves from the point of view of gyroscopic action.

As we have already said, the force ψ given by formula (13) and (13') is a horizontal force applied at the inside wheel (of the curve) of the leading axle and acting towards the centre of the curve, and a force $-\psi$, also in a horizontal direction applied to the outside wheel of the trailing axle. The moment of these forces tends to turn the locomotive about the axis z in a negative direction, and consequently causes the tyres to slip sideways upon the rails.

To these forces are opposed the friction between the tyres and rails. The above mentioned lateral slipping will be prevented if the following conditions are satisfied :

$$f \Sigma p'_n \delta_n \geq \frac{i \cdot V^2}{g \cdot s} \Sigma \frac{p_n \rho_n^2}{r_n} \quad (17)$$

for steam locomotives, and

$$f \Sigma p'_n \delta_n \geq \frac{i \cdot V^2}{g \cdot s} \left(\Sigma \frac{p_n \rho_n^2}{r_n} + K \Sigma \frac{p_m \rho_m^2}{r_m} \right) \quad (17')$$

for electric locomotives.

In these expressions :

f = coefficient of friction between wheel and rail,

p'_n = total weight of the axle and its load,

δ_n = distance of the n^{th} axle to the vertical axis through the centre of gravity. From (17) and (17') we may deduce the maximum value of i :

$$i = \frac{f \Sigma p'_n \delta_n}{\frac{V^2}{g \cdot s} \Sigma \frac{p_n \rho_n^2}{r_n}} \dots \dots \quad (18)$$

$$i' = \frac{f \Sigma p'_n \delta_n}{\frac{V^2}{g \cdot s} \left(\Sigma \frac{p_n \rho_n^2}{r_n} \pm K \Sigma \frac{p_m \rho_m^2}{r_m} \right)} \quad (18')$$

For the steam and electric locomotives considered above, for speeds of 200 km. (124.3 miles) an hour, it will be found that :

$$i \leq 44 \text{ thousandths;}$$

$$i' \leq 29 \text{ thousandths.}$$

The value of M_z for the steam and electric locomotives, supposing the inclination of the outer rail is 20 thousandths, is :

$$M_z = 36\,120 \text{ kgm. (261\,261 foot-pounds);}$$

$$M'_z = 54\,800 \text{ kgm. (396\,376 foot-pounds).}$$

In practice, it is customary to give the outer rail of a transition curve an inclination of 2 to 3 thousandths, that is, a tenth of the limiting inclination.

For an inclination of 2 thousandths,

the values of the gyroscopic moment are as follows :

$$M_z = 3\,612 \text{ kgm. (26\,126.1 foot-pounds);}$$

$$M'_z = 5\,480 \text{ kgm. (39\,637.6 foot-pounds).}$$

We may ask whether there is a limit of inclination imposed by the conditions of stability against derailment but it should be noticed that the force ψ tends to force the leading wheels against the inside rail, that is to say, to the side opposite to that against which a derailment may occur. Any further investigation is therefore unnecessary.

In the case where the rotors of electric motors turn in the opposite direction to the wheels, they produce a positive moment, that is to say, they tend to force the leading wheels against the outside rail, but the value of this moment is as a rule exceeded by the negative moment due to the rotation of the wheels.

Initial causes of rail breakages, and methods employed to reduce the number,

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Figs. 1 to 8, pp. 503 and 505.

I. — Initial causes of breakages.

a) Piping is caused by the reduction in the volume of the liquid steel when passing into the solid state. The surfaces of the piping do not weld up. Traces of this are always found in rolled sections if insufficient discard has been cut from the head of the ingot. Figure 1 shows a fish-plate bolt divided symmetrically by piping. In the case of rails the position of the piping is not always regular. In figure 2 it is, it will be seen, along the vertical axis of the rail; this defect was not visible at the ends of the rail, but only at the middle portion of the rail head which had spread 5 cm. (2 inches).

Dissymmetrical piping at the end of the rail in the portion held in the fish-plate (fig. 3) had been present in the centre of the head and spread towards the upper surface on one side and the web of the rail on the other, where it separates the portion between the bolt holes. New cracks developed from the piping to the surfaces of the web of the rail and reduced its strength.

The horizontal piping (fig. 4) divides the head of the rail into two portions; in many cases the head of the rail is totally separated from the web.

These are the most frequent types of piping which in every case produce *longitudinal fractures*;

b) Blow holes : liquid steel contains a considerable amount of gas : at the moment of solidification the gas is liberated and forms small cavities or blow holes in the metal. Attempts are made to prevent the liberation of gas during the solidification by the addition of suitable deoxidisers. If the interior surfaces of the blow holes are clean, they weld up under the pressure of the rollers and no trace is found after rolling. If this is not the case, small portions flake off from the upper surface of the head of the rail;

c) Impurities (inclusions of slag) : their concentration is known as segregation. There are metallic impurities (phosphates, silicates and sulphates of iron) and non-metallic impurities (oxides of Fe, Si, Mn and silicates of Fe, Mn). These are always found to a greater or less extent in steel produced by an oxidation process;

d) Reduction of the section by excessive wear;

e) Reduction of the section by corrosion in tunnels, at level crossings and at



Fig. 1.



Fig. 2.



Fig. 3.



Fig. 4.

stations, etc. The rate at which corrosion takes place depends upon the quantity of impurities.

II. — Supposed causes of breakages.

a) Hardening of the upper surface : it has been found that a considerable proportion of the breakages take place as a result of surface defects which are produced by hardening due to slipping. These superficial defects are visible without any special treatment of the upper surface of the rail in the case of rails near to signals protecting stations where severe brake applications are made. However, during 29 years experience on railways, I have never found that these cracks extend from the outer surface into the interior; on the contrary, when it has been necessary to replace these rails it has been found, by cutting them, that there are initial cracks in the centre of the rail head which are due to piping (figs. 5 and 6);

b) Lamination : one often finds rails, especially in stations, which are badly laminated, but although these look very unsatisfactory, they do not break. Lamination is not a cause of rail breakages;

c) Influence of frost : good rails do not break either in winter or in summer; as, however, more breakages occur in winter, it is necessary by tests to ascertain whether defective metal is more brittle during this season. One might conduct comparative tests on test pieces 8×10 mm. ($5/16$ in. $\times$ $3/8$ in.) taken from the same rail at temperatures, for example of 15° , zero, -10° , -20° (59° F., 32° F., 14° F., -4° F.) in accordance with the « New methods of testing rails ». The desired temperature might be artificially obtained.

III. — Methods of reducing the number of breakages.

In our opinion the only precautions that can be taken lie in the method of manufacture and in the specifications.

The most dangerous fractures, which sometimes cause the rail to break into a number of pieces, are due to impurities in the metal. These may be detected by etching, but this test, although very effective, gives us no information as regards the brittleness of the metal. M. Frémont has found that rails of a very heterogeneous structure are not always brittle, although their strength is considerably reduced by segregation.

As a rule for this test the rails are cut transversely. To determine whether the impurities extend regularly in a longitudinal direction, we cut a rail which had broken in service along its axis, and found that in the upper layers the impurities were distributed in a regular manner, whereas those in the centre of its section were irregular and in patches. In practice, transverse fractures are often very irregular (fig. 7).

Figure 8 shows an irregular fracture of this kind : the bright portions of the fracture containing light green impurities, which, when attacked by hydrochloric acid, produce a smell of sulphurated hydrogen, being no doubt an agglomeration of iron and sulphide.

All experienced engineers are fully aware that with small ingots which cool down rapidly less piping occurs than with large ingots; moreover, the quicker the steel solidifies the less segregation there is. Mr. Wickhorst has studied the influence of the size of ingots on segregation, and the results of his researches confirm this opinion. However, one can hardly hope that the steel works will ext-



Fig. 5.



Fig. 6.

(Same rail as figure 5.)

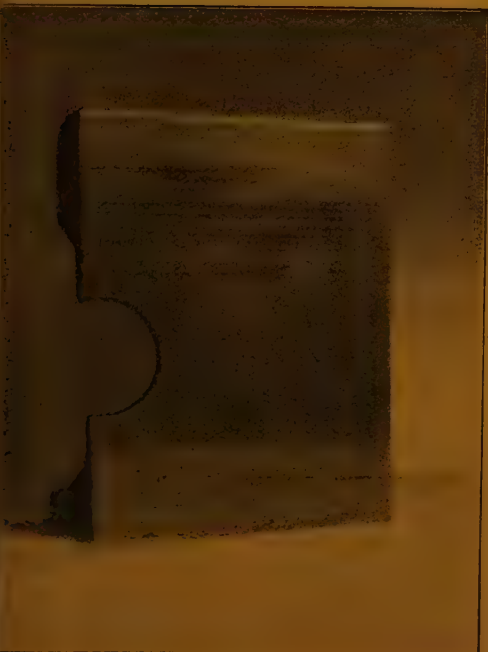


Fig. 7.



Fig. 8.

end the use of small ingots for the manufacture of rails without increasing the cost. It is therefore necessary to look for other remedies.

The prevention of piping by compressing the ingots in Harmet or Whitworth presses during the solidification of the metal is very costly and of no value in the case of the material in question.

In America, in 1912, 5 000 t. of rails were rolled from electric furnaces; none of these rails has broken after a year of service, while rails made by other processes have given rise to a number of breakages in the same period. The financial situation in Europe does not allow us to follow the American example in view of the increase in the cost of manufacture. According to Dr. Rosenhain, the non-metallic enclosures are due to fluid or semi-fluid, non-metallic substances formed by contact with the steel or expelled from the steel during the operation of melting or pouring, and are included in the steel which has solidified

before they were able to separate out. If the solidification had taken longer and other conditions had been favourable, they would have been expelled from the steel. There are economical methods of manufacture which allow the steel to remain in a liquid state in the upper part of the ingot sufficiently long to allow this to be fed in such a way as to almost completely avoid piping and to localise the segregation in the head of the runner. The least costly methods are the use of a sink head and of heating the head (Hadfield's process).

Conclusion.

To avoid rail breakages, one may improve the metal in the ingots by relatively inexpensive methods, *i. e.*, by localising the piping in the head by keeping this heated. The best specifications are not sufficient to guarantee that rails made under the conditions laid down will not break sooner or later.

CONDUCT OF WORK.

(From the *Bulletin of the American Railway Engineering Association.*)

A number of regulations in connection with work on the track, accepted by the American Railway Engineering Association, is given below for information.

ROADBED.

Drainage.

General.

670. Thorough drainage of the roadbed is absolutely necessary before good track can be secured or maintained, and this matter must be given careful detailed consideration at all points.

Surface drainage.

675. Ditches must be kept open at all times so as to divert the water from the roadbed quickly. Ditches must be dug out thoroughly and restored to full size in the spring and late fall. Side ditches must be dug uniformly and parallel with the track, and conform to the standard roadbed sections.

676. Intercepting ditches must be constructed along the top of the bank for the protection of cuts, where the drainage area would be likely to collect sufficient water during heavy rains, from the higher ground adjacent, to wash the slopes.

677. The end of a ditch must be diverted from the track, so that the scouring action of the water will not weaken or wash away the roadbed.

678. Waterways leading to and from bridges and culverts must be kept clean within the limits of railroad property. Culverts must be kept open for the free and unobstructed passage of water at all times.

679. In regions of heavy snows, ditches must be cut through the snow, wherever a sudden thaw would be likely to flood the track, and all ditches must be cleaned when the snow is melting in the spring.

680. Cross-drains must be put in at proper intervals, where directed by the.....

Underground drainage.

685. In wet or narrow cuts, where side ditches cannot be effectively maintained, sub-drains must be provided, as directed by the who will determine the size and character of drains to be used. Such drains must be laid to a true grade and in conformity with standard plans.

CARE OF ROADWAY.

General.

690. The cross-section of the roadway must conform to the standard plans. No deviation from the sections shown shall be made without proper authority.

691. Growth of vegetation on the slopes of cuts and embankments shall be encouraged to prevent erosion.

TRACK.

Ties.

(Storage of)

695. Ties stored along the right-of-way must be stacked to conform to the

standard plans, according to class, shape and location. Stacks must be placed on ground bare of debris or vegetation for at least two feet around each stack and clear of vegetation over six inches high within ten feet of any stack, and sufficiently well drained so that water will not stand under the stacks or in the immediate vicinity. Decaying wood debris must be entirely removed.

Renewals (Inspection for)

700. The ties in track must be inspected at stated times each year and those which will not last until the next inspection marked for renewal. This inspection shall be made preferably by the supervisor personally, accompanied by the section foreman. The supervisor must report to the division engineer on the proper form, the number of ties marked for renewal on each mile and each section. This report shall be carefully checked by the division engineer and where any unusual or unfavorable condition is indicated, a thorough investigation shall be made to insure proper renewals.

Renewals (Method of)

705. The renewal of ties shall be started when directed by the division engineer. All defective ties removed from track each day must be placed for burning or loading on cars. The supervisor must frequently inspect ties removed from track to see if any have been removed which might have remained in the track with safety until the next inspection.

706. Ties must be spaced according to the standard plan. All ties shall be placed square to the line of rails. The outside ends on double tracks, and the ends on one side throughout on single track, must be lined parallel with the rail.

707. Ties must be laid so as to obtain the best bearing. Untreated ties must be placed in track with the wide surface

having the most heartwood down; treated ties must be placed in track with wide surface nearest the pith down, or if the pith is not present in the tie, with the widest surface down. Ties shall be adzed only when necessary to obtain a full bearing under rail or plate.

708. Ties must be moved with tongs so as to reduce the damage incident to handling; picks, mauls, sledges and spiking hammers must not be used in moving ties or placing them in position beneath the rail.

Use of tie plugs.

710. Whenever spikes are drawn from ties, creosoted tie plugs must be driven into all holes except in ties which are to be renewed that season. In replacing spikes, they must be driven into the plugs.

Records.

715. Accurate records of tie renewals and all data of value in connection therewith must be kept on prescribed forms.

RAIL.

Renewals.

720. The most expensive and the most easily damaged part of the track structure is the rail, therefore care must be exercised in unloading and handling. In unloading from cars, rail must be skidded or otherwise carefully lowered to prevent injury. Where it is necessary to drop it, both ends must be dropped at the same time, and the greatest care taken to avoid its falling on hard or uneven surfaces. Rail received in gondola cars should be unloaded with an approved device to prevent injury.

721. Rail must be distributed, as far as practicable, where it can be laid with the least amount of handling. Unless rail is to be laid at once, it must not be distributed through yards and station grounds where trainmen and others are liable to stumble over it.

722. Rail laying may be done in the winter months, or at such seasons of the year, depending on the climate, unfavorable for doing other track work.

	33-ft. rail.	39-ft. rail.	45-ft. rail.
— 20° to 0°	5/16 inch.	3/8 inch.	7/16 inch.
0° to 25°	1/4 inch.	9/32 inch.	11/32 inch.
25° to 50°	3/16 inch.	7/32 inch.	1/4 inch.
50° to 75°	1/8 inch.	1/8 inch.	5/32 inch.
75° to 100°	1/16 inch.	1/16 inch.	1/16 inch.
Over 100° rail to be laid close.			

Care must be taken that the openings between rails be not more than above limits, as too much expansion in the joints will cause more rapid injury to the rail than any other error or defect in the method of laying, especially under heavy traffic.

724. Care must be exercised by those in charge of rail laying gangs to see that adzing is carefully done and rail left in proper line, gage and surface. Shims must be used if the track is frozen and ties cannot be lifted to eliminate low spots. Tie plates and anti-creepers must be placed the same day rail is laid. It is especially important to prevent creeping of rail by applying a sufficient number of anti-creepers at once, as rail creeping changes the expansion in the joints, making some joints wide and others close, resulting in battered joints, and in hot weather danger from buckling of the track where joints are tight.

725. Rail shall not be curved before laying except for curves above ... degree.

726. Kinked or crooked rail must be straightened before being laid; if surface bent, it must either be straightened or removed.

727. In making temporary connections in main tracks, an old rail must be cut and fastened to the new rail, using compromise joints when necessary.

728. When replacing rail of approximately the same width of base, so that the tie plates need not be changed, but two lines of spikes are to be drawn. When a different tie plate is required, all

723. Where practicable, rail must be laid one at a time. Standard expansion shims must be used. The openings between rails shall be as follows :

spikes must be drawn. Where no tie plate is required, all spikes must be drawn. Where no tie plates are in use but three lines of spikes need be drawn for any change in the width of base of rail.

729. Spikes shall be driven vertically with face in contact with the base of rail. They must not be straightened while being driven. Rail must be full spiked, and the spikes staggered so that outside spikes will be on the same side of tie, and inside spikes on opposite side. Where shoulder tie plates are used, a third spike may be driven on inside of rail, with back of spike against base of rail. Good second-hand spikes must be used for the third spike.

730. Joint bars must be securely fastened with the full number of bolts. At permanent connections of rail of different sections, compromise joints must be used.

731. For the preservation of the rail, and to secure the proper bearing for carrying the loads, and distributing the weight of the rolling stock uniformly over the rail and to the roadbed, the ties must be spaced uniformly. Twenty (20) ties to a thirty-three (33) foot rail and eighteen (18) ties to a thirty (30) foot rail shall be used.

Bonding.

735. Where track circuits are used for operation of signals or other purposes, bonding of rail is necessary. This feature must receive proper consideration

and the work be carefully and efficiently performed. Where air, electricity or other power is available, any mechanical arrangement which will operate drilling machines successfully is preferable.

Replacement (Inspection of rail in track).

740. Accurate records of rail renewals and all data of value in connection therewith must be kept on prescribed forms. These records must be kept up to date. Every change, whether of individual rails, or many rails, being recorded immediately.

741. Track walkers must be properly instructed to look for broken or defective rails, and report same, when discovered, to the section foreman, taking proper precaution to protect traffic, if necessary, on account of the condition of the rail found.

742. Where rail failures become numerous, especially if transverse fissures develop, a special rail inspection may be arranged. This can be facilitated by the use of a mirror attached to a short wire handle for examining the inside and underside of the head of the rail. A good magnifying glass with which minute defects or hair line cracks can be inspected, is desirable.

Broken rails.

745. A broken rail found in the main track must be protected immediately by a flagman and no trains allowed to pass over it until it is determined that the rail is in such condition as will permit the safe passage of trains. If it is decided trains may pass over the rail safely, all trains must be stopped before reaching the break, and then allowed to proceed at slow speed. If a suitable rail is available, the broken rail must be replaced immediately; otherwise, if practicable, the broken ends of the rail must be connected by joint bars, the rail drilled and the joint bars full bolted, after which the resumption of traffic may be permitted.

JOINT BARS.

750. Joints must be kept well oiled, both as a preservative from rust and to facilitate expansion and contraction of the rail.

751. Insulated joints must be installed only on rails conforming to the section for which they are designed. Care must be taken, when installing such joints, to properly place the insulation, and not to damage the fiber or bushings. Ties under and adjacent to insulated joints must be kept well tamped.

752. Before applying an insulated joint, all scale, dirt and other foreign matter must be removed from the rail end and joints parts. Clean smooth bearing surfaces are necessary to obtain good fit and durability. All burrs, lips and rough edges, which might cut into the insulation must be removed from the rail ends, by cutting or filing them off before the joint is applied.

Track bolts.

755. As large track bolts must be used as the holes in rail and joint bars will permit.

756. Track bolts must be kept tight and well oiled.

757. Track bolts must be gone over and re-tightened after new rail has been laid, as soon as traffic has worn the mill scale and rust off the joint bars and settled the bars into place.

758. Proper wrenches for tightening track bolts shall be furnished and must be used without modification. Care must be exercised in tightening bolts to avoid twisting the bolt or stripping the thread.

SPRING WASHERS.

760. Spring washers must be used on all track bolts.

TRACK SPIKES.

765. Spikes must be driven until the heads are in contact with base of rail,

but not driven too far, thereby bending the neck and causing the head to crack or break off.

766. Badly bent, crooked, or neck-cut spikes must not be used, especially in main track. Good spikes, which are bent, must be straightened before being used.

ANTI-CREEPERS.

770. Anti-creeper must be applied where directed by the The number of anti-creeper per rail will depend upon the physical characteristics of the track and amount and character of traffic.

771. In the application of anti-creeper care must be exercised to use proper tools, properly apply the anti-creeper, and not damage any of the parts. The use of spikemauls or heavy hammers is prohibited.

TIE PLATES.

775. Tie plates must be used where directed by the

776. When applying tie plates care must be exercised to see that the plates have a full, even bearing on the ties, that the track is in correct gage before they are spiked to the tie, and that the shoulder of the plate rests against the base of rail for the full width of the plate. The shoulder of the plate must not be under the base of rail.

BALLAST.

Cross-section.

780. The cross-section of the ballast must conform to the standard plans.

Unloading.

785. When unloading ballast, care must be exercised to secure proper disposition and avoid waste. If special ballast cars are not available, hopper bottom cars must be used.

Ballasting.

790. Track must be kept in good line and surface while ballasting. The ballast program should be so arranged, and the supply so regulated, as to leave the least possible open track when the season closes. During the progress of ballasting, open track must be watched carefully and protected with the prescribed slow signals, if necessary.

791. Where directed by the division engineer, preparatory to the distribution of new ballast, all old ballast and unsuitable material must be removed to the bottom of the ties, for the full width of the roadbed, the old ballast cleaned, and the unsuitable material used for widening embankments or for other purposes. At the same time, all ties requiring renewal must be replaced and the ties properly spaced, if necessary.

792. When old ballast has been thoroughly cleaned, sufficient new ballast should be unloaded to make the first raise, which is usually made by shovel tamping the ties. When ballasting or surfacing track out of face, both rails must be raised together.

793. Section foremen must provide proper protection by slow order, caution signs, or flag, or all of these, if necessary, when raising track, and must, except in emergency, raise against the current of traffic, where there is more than one track. A long easy runoff must always be prepared ahead of fast passenger trains.

794. In gravel or broken stone ballast, the ties must be tamped from fifteen inches inside the rail out to the ends. If possible, the end of the tie outside of the rail must be tamped first and a train allowed to pass over before tamping on the inside of rail. The space under the rail must be tamped well. The center of the tie must not be tamped.

795. Where track is electrically bonded, the ballast must be kept at least one inch below base of rail. At road cross-

ings, platforms, etc., where this is not practicable, rails may be insulated by painting them with an asphaltum or tar product, and good, clean stone mixed with the same material may be used for at least one foot each side of rails.

796. The following tools shall be used. For broken stone or furnace slag ballast: Shovel, tamping pick and stone fork. For gravel, chats, chert or cinder ballast: Shovel, tamping pick or tamping bar.

LINING AND SURFACING.

811. As early in the spring as the weather and track conditions will permit, the entire section must be gone over and smoothed up. At this time special attention must be given to those portions of the section on which no tie renewals or ballasting is expected to be done during the season, and this track put in 100 % condition. Where tie renewals are to be made or ballasting is to be done, no unnecessary work shall be done, the aim being to keep these portions of the section sufficiently smooth for safe and comfortable riding, until the work of renewing ties or ballasting can be accomplished.

812. Where the track shows evidence of being badly out of line on curves and there is opportunity to do so, line stakes shall be set by engineers. [Section foremen, assisted, if necessary, by the supervisor, can line the track very accurately and secure practically perfect riding curves by the use of a string sixty-two feet long, holding the ends against the gage side of the high rail and measuring the distance from the middle of the string to the gage of rail, each inch of distance representing one degree of curve.]

814. When raising or surfacing track, foremen must not trust to their eyesight alone, but must use the track level boards and sighting boards. Track level boards must be tested frequently.

815. When not surfacing out of face, as in case of picking up joints or other low places, the general level of the track must not be disturbed.

Shimming.

820. Wooden shims placed under the rails must be used to maintain the proper surface of the track, when the surface is disturbed by the action of frost, or when other conditions make tamping impracticable.

821. When shimming, the track level and track gage must always be used.

822. Shimming must be done on top of the tie. No shimming shall be done under the tie, except in emergency and shims so placed must be removed as soon as possible.

823. Shims must be the same thickness throughout, and not wedge shaped; they must have an even bearing on the tie.

824. Where shims are used the rails must be securely braced to prevent spreading. [Tie plates with one end placed against the outside under the head of the rail, and the other end spiked to the tie may be used when other braces are not available.]

825. Section foremen must watch track which has been shimmed, testing frequently with the gage and level board to make sure that shims are in place and tight and that track does not get out of gage or surface.

826. When the frost is leaving the track, shims must be changed frequently, replacing thick shims with thinner, until the necessity for shims has passed. As soon as the frost is entirely out of the track, all shims must be removed and the track surfaced, if necessary. Care must be exercised, however, that track surfacing is not done before the frost has all gone.

Gaging.

830. Uniform gage is essential to good track and must be maintained.

831. The standard gage is 4 ft. 8 1/2 in. Curves of eight degrees and under shall be standard gage. Gage shall be widened 1/8 inch for each two degrees or fraction thereof over eight degrees, to a maximum of 4 ft. 9 1/4 in. for tracks of standard gage. Gage, including widening due to wear, must never exceed 4 ft. 9 1/2 in.

832. Where frogs occur on the inside of curves, the gage at the frog must be standard, unless a frog with widened flangeway is used.

833. If the track is allowed to remain out of line or out of surface for any length of time, bad gage is likely to result therefrom, therefore section foremen must always check the gage and make any necessary corrections when lining and surfacing the track out of face.

834. Track gages must be checked frequently with a standard gage to assure that all gages are correct. This shall be done each year in the winter months, and the gages painted a new standard color each time tested.

Elevation of curves and easements at ends of same.

840. The elevation on curves and the easements at the ends of same must be in accordance with requirements and according to prescribed standards.

841. Where the maximum speed allowed by timetable is higher than the maximum standard elevation will safely permit, the speed must be reduced accordingly. Signs shall be placed at the beginning of each curve where the speed must be reduced below the maximum allowed by the timetable. The signs shall show in plain figures the maximum permissible speed.

842. The maximum elevation on any curve must not exceed seven and one-half inches. Speed is the principal factor in elevation on curves, and the degree is a secondary factor only. Section

foremen must not vary from the prescribed elevation without proper authority. Where there is considerable freight traffic and passenger traffic is not so important, it is preferable to keep the elevation low on the curves, and slow down the passenger trains to meet the conditions.

843. Where possible, posts must be placed at the side of the track for the guidance of section foremen. These posts, indicating the elevation in inches and fractions thereof, shall be set at the beginning of the easement; at the beginning and end of the regular curve, and at the end of the easement or point of the tangent. Posts must also be set at the points of compound and at each end of easements, between compound curves.

FROGS AND SWITCHES.

851. Track must be kept in good line and surface through frogs and switches, and section foremen must give these features special attention.

852. Switches and frogs must be inspected as directed by the to see that they are in proper working order, and that all nuts, bolts and other fastenings are in place and properly tightened. Any broken or damaged parts must be replaced promptly.

853. Switch points must fit closely and accurately to the stock rail, which must be bent in accordance with the prescribed standards. When renewing a switch point, the stock rail must also be renewed, if necessary to secure a proper fit of the point. In like manner a new stock rail should not be used with a worn point, in order to prevent danger of derailment if the stock rail is higher than the switch point.

854. Frogs must be protected by guard rails, constructed and placed in accordance with standard plans. The tops of the guard rails must be level with the main running rails, and must be securely held in place.

855. Guard rails must be so placed that the gage distance from the frog point to the flangeway side of the guard rail will be at least 4 ft. 6 3/4 in., and the distance between the flangeway sides of the wing rail and guard rail shall not exceed 4 ft. 5 in.

For the widening of gage and flangeways on curves for the operation of specific locomotives or for special conditions and for curved crossings, refer to Tables No. 1 and No. 2 for « Gages and Flangeways in Curved Tracks ».

856. Switch rod and connecting rod bolts must be equipped with cotter pins. Bolts must be inserted with the nut on top for convenient inspection.

857. Switches must be kept free from obstructions at all times and free from ice and snow in winter. The slide plates must be kept well oiled.

858. Switch stands must be kept firmly spiked to the head-block ties, must be set plumb, and with the target square with the track.

859. Automatic switch stands must be inspected frequently for lost motion. They must be kept well oiled. Head-block ties must be kept firmly tamped.

860. Switch stands must be placed, wherever possible, on the side of the track where the connecting rod will be in tension when the switch is set for the main track. The switch banners and lamps must be placed on the right hand or engineer's side of the track approaching facing point switches.

861. Switch stands and facing point switches on multiple tracks and main track switches on single track must be equipped with switch lamps of approved design, which will show the « proceed » color when switch is set for the main track, and the « stop » color when switch is open.

862. Unless otherwise provided for, section foremen will be responsible for the proper care and maintenance of switch stands and lamps and must give these devices careful attention. Switch

stands must be kept tight on the head-blocks and adjusted to give the switch the proper throw and to keep the points tightly against the rails, when the switch is closed, either for the main track or the turnout.

863. Switch lamps must be kept clean, supplied with oil, properly adjusted, and firmly placed on the switch stand, so they will not jar out when the switch is used.

864. Main track switches, not interlocked, must be kept locked at all times except when in actual use by trains, or when being inspected. Section foremen must report immediately main track switches found unlocked or with the lock missing.

SWITCH TIES.

870. Switch ties must be used for all permanent turnouts, crossovers and railroad crossings, and must conform to the standard specifications. They must be placed in track in accordance with the standard plans.

871. For temporary work, track ties may be used, lapping them in place of switch ties, but switch ties must be used for head-blocks and for at least three or four ties under the frog and guard rails.

TRACK SIGNS AND POSTS.

875. Track signs and posts must be placed and maintained in accordance with standard plans and special instructions.

876. Section foremen must see that all track signs and posts are in their proper places and kept plumb, and that weeds and other vegetation are not permitted to obscure the view of same.

ROAD CROSSINGS.

880. Section foremen will be responsible for the proper care and maintenance of public and private road crossings.

881. Road crossings shall be constructed and maintained according to standard plans, and must conform to legal requirements.

882. Road crossing signs, where required by law, must be maintained. Such signs must be properly placed and kept clear of obstructions which would interfere with the view of travelers on the highway. Where possible, the permission of adjacent landowners should be secured, if necessary, and all brush or trees, obscuring the view of approaching trains, removed.

Track tools.

891. All track tools are furnished by and remain the property of the Company.

892. Section and other foremen in charge of men will be held responsible for the proper care and use of tools.

They must know that they have at all times a sufficient supply, in serviceable condition. They must see that tools are not lost or broken, and when not in use, are not left where they are liable to be struck by trains or derail trains.

893. When not in use, all tools must be collected and properly protected from the weather and from being stolen. Where it is not practicable for foremen to take all tools to the toolhouse each evening, suitable tool boxes, equipped with substantial locks, shall be provided, and all tools must be placed therein each night.

894. Labor-saving devices and appliances must be used wherever such use is economical.

895. Rail-handling and rail-laying machines or locomotive cranes shall be used in laying rail, where available.

[624 .432 .5 (.73)]

Simple Mallet 2-8-8-2 locomotives for Great Northern Railway (United States),

By W. W. BAXTER,
EDITOR, MECHANICAL DEPARTMENT.

Figs. 1 to 7, pp. 516 to 523.

(From the Railway Review.)

Four of the largest and most powerful simple articulated freight locomotives thus far constructed by the Baldwin Locomotive Works, and the largest engines in the Northwest territory, have been placed in service recently by the Great Northern Railway. They are of the 2-8-8-2 type, designated by the road as the class R-1-S., and are intended for service between Cut Bank and Whitefish, Montana, 128 miles, where the road crosses the Continental Divide. The ruling grade approaching the summit at

this point, west bound, is 1 %, while east bound it is 0.8 %, with a pusher grade 1.8 % 13.8 miles in length. The elevation at the summit is 5 211 feet. The sharpest curves on this section of the road are ten degrees, although the engines were designed to traverse curves as sharp as 20°.

Since late in 1923 the heavy freight traffic on this division has been handled principally by locomotives of the Santa Fe or 2-10-2 type which were also built by Baldwin. These engines develop a tractive force of 87 100 pounds. Four of

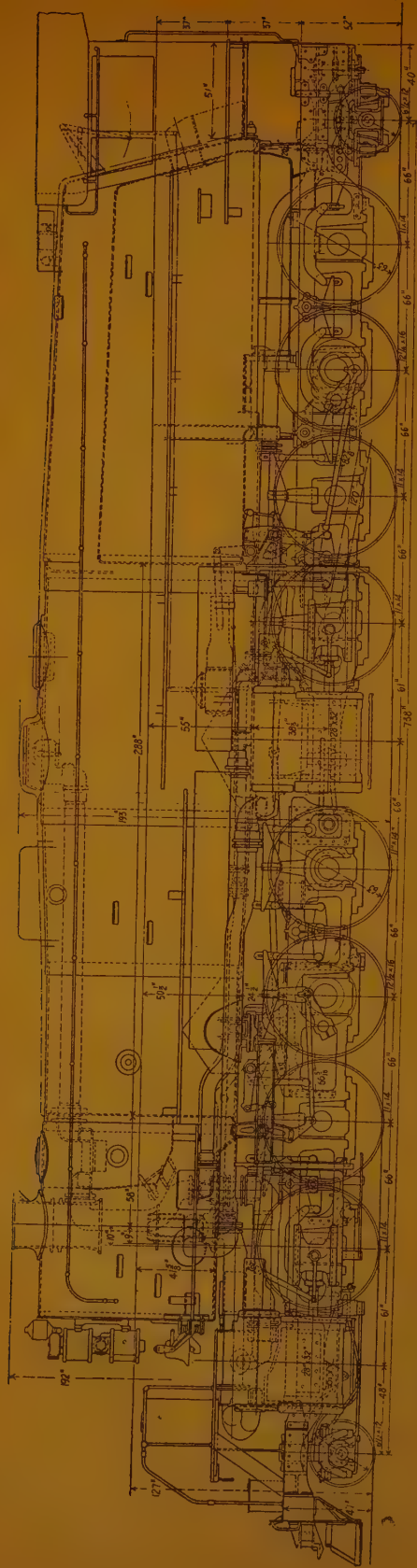


Fig. 1. — Side elevation of powerful new simple articulated locomotives of Great Northern Railway, built by Baldwin locomotive works.

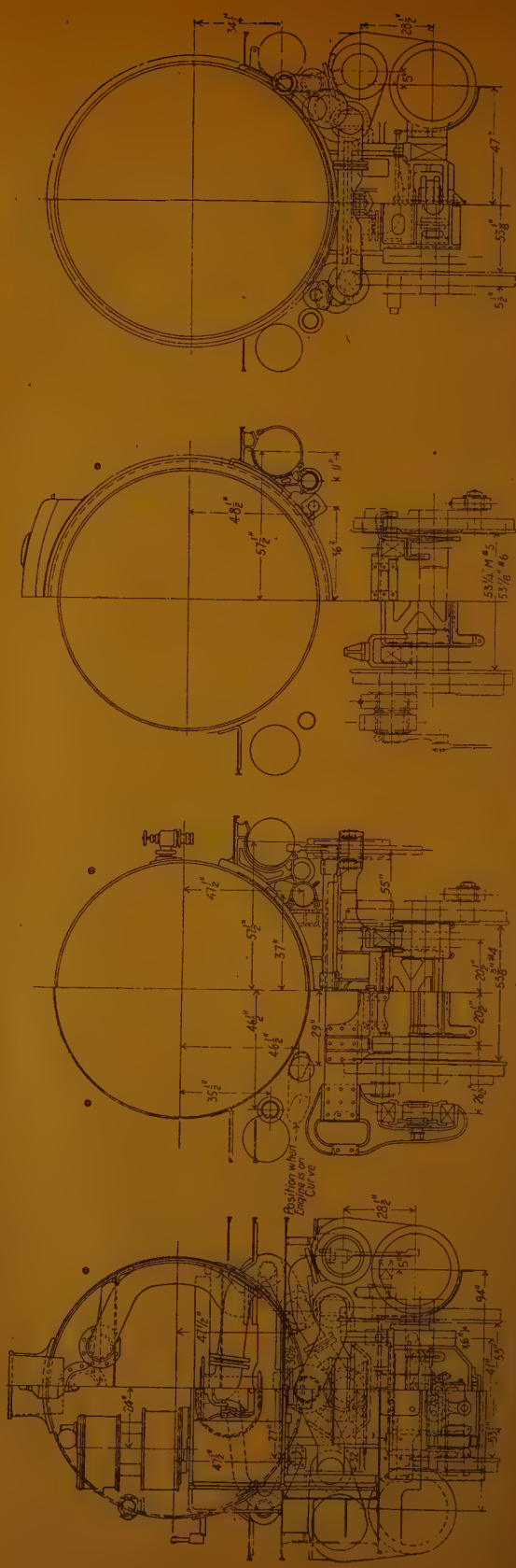


Fig. 2. — End elevations and cross sections of forward unit of new simple articulated freight engines of Great Northern Railway.

them, equipped with boosters and having a maximum starting effort of nearly 100 000 pounds, are used as helpers on the 1.8 % grade. As compared with the road engines of the 2-10-2 type the new single expansion articulated engines show an increase of nearly 47 %, which, as is evident, will greatly increase the capacity of that portion of the road between Cut Bank and Whitefish.

The largest articulated locomotives heretofore used by the Great Northern are 25 Mallet compound engines of the 2-8-8-0 type, known by the road as the class N-1, built by the Baldwin Locomotive Works in 1912. During the past year several of these locomotives were converted from compound engines to simple articulated locomotives, using high pressure superheated steam in all four of the cylinders, which are of the same size.

The work of changing these engines from compound to simple locomotives consisted essentially in bushing the high pressure cylinders, applying new cylinders in place of the low pressure cylinders, and the application of an entirely new set of steam and exhaust pipes. The general arrangement and application of these various pipes is shown in the figures 5, 6 and 7.

Outside steam pipes, equipped with expansion joints, were applied, extending from the smoke box to the rear cylinders. At the joints of these steam pipes, at the smoke box, both of the outside pipes were fitted with flanged elbows having side outlets for Y connections, which extend beneath the boiler to provide a passage for steam to the front steam pipe, through which steam passes through another connection into the valve chambers of the front cylinders. The front steam pipe is fitted with both ball joints and expansion joints. Instead of two separate exhaust pipes for the two sets of cylinders only one was applied, so arranged that exhaust steam from the front cylinders passes through the center opening in the exhaust pipe, while

that from the rear cylinders passes through the cored side openings.

No dynamometer car tests have as yet been made as a basis for comparing the converted simple articulated engines with the Mallet compounds, before conversion, but road tests have clearly demonstrated the possibilities of an increase in hauling capacity, with a material reduction in the amount of coal and water consumed per unit of work. On one district, having ruling grades of 72 % the converted engines have handled approximately 1 000 tons more, in practically the same running time as that made by the Mallet compounds, with a reduction in the consumption of both fuel and water. The older compound engines formerly handled trains of 4 250 tons over this district while the converted engines are capable of hauling trains of 5 200 tons over the same territory. This probably is due to the fact that the older engines had a rated tractive effort of 93 250 pounds, with a factor of adhesion of 4.5 while the converted single expansion engines develop an initial starting effort of 100 000 pounds with a factor of adhesion of 4.2. The satisfactory results in increased capacity and economy in the operation of the converted engines were the determining factors in the selection of the type and design of the new class R-1-S engines.

The only other well known locomotives in this country of the same type as that of the new motive power of the Great Northern, which might be favorably compared, are the 2-8-8-2 type simple articulated engines of the Chesapeake & Ohio Railway. These engines were fully described in the *Railway Review*, 5 April (1), 1924. They have four cylinders 23 inches in diameter with a stroke of 32 inches; driving wheels 57 inches in diameter; a length over engine and tender of 103 feet 3 3/8 inches,

(1) See *Bulletin of the International Railway Congress Association*, July-August 1924. p. 575.

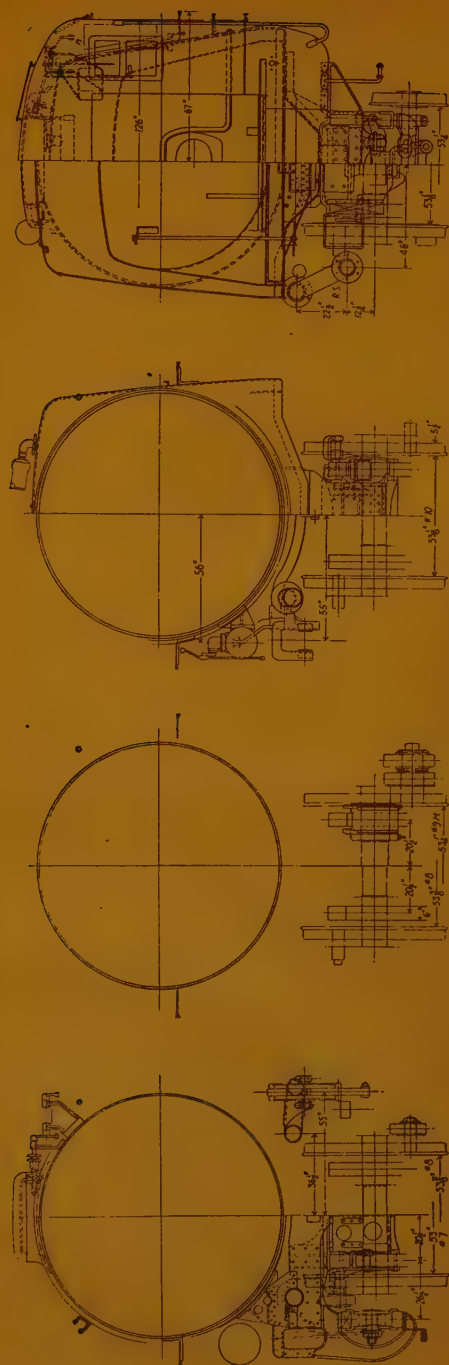


Fig. 3. — End elevations and cross sections of rear unit of Great Northern new simple articulated freight locomotives.

and a total weight of engine and tender in operating condition, of 774 000 pounds, with a maximum tractive effort of 103 500 pounds. The new class R-1-S engines of the Great Northern have four cylinders 28 inches in diameter with a stroke of 32 inches; driving wheels 63 inches in diameter; an overall length of 107 feet 2 1/4 inches, and a total weight of engine and tender, loaded, of 916 500 pounds, with a tractive power of 127 500 pounds. In fact the Great Northern engines are almost equal in size and power to the 2-8-8-0 Mallet compounds of the Pennsylvania Railroad, and the 2-10-10-2 articulated compound engines of the Virginian. The former have a total weight of 794,000 pounds and develop a starting effort of 135 000 pounds, while the latter weigh 898 300 pounds and are capable of developing a starting power of 176 600 pounds simple, and 147 200 pounds while working as compound engines.

Track conditions on the Great Northern have been much improved since the class N-1 locomotives were constructed. With the wheel loads now permitted it is possible to apply a boiler of sufficient capacity to insure an abundant supply of steam for the four 28 by 32-inch cylinders used on the class R-1-S locomotives.

In accordance with the usual practice on this road, the boilers of the new class R-1-S engines are of the Belpaire type. The barrel has a conical connection, and is 100 inches in diameter at the front end, the maximum diameter being 109 inches. It is fed by one Sellers non-lifting injector placed on the left side, and by one Elesco exhaust steam injector on the right side. The combustion chamber has a length of 72 inches, and the tubes are 24 feet long. The locomotives as built are equipped for burning oil, but the design is so arranged that they can subsequently, if desired, be equipped to burn coal. They are also so constructed that they can be fitted with brick arches and mechanical stokers. At present no arch tubes are applied, but a brick wall

is placed across the throat of the combustion chamber.

Flexible staybolts are applied in the breaking zones in the sides of the firebox. Hollow stays are used in the back head and back of the brick work, and there is a complete installation of flexible bolts in the firebox throat and the combustion chamber.

The main dome is on the third boiler ring, and back of it, on the same ring, is a man-hole opening fitted with a depressed cover, in which are mounted the whistle and the four safety valves. This arrangement was necessary in order to keep within the over-all height limit.

A throttle valve of the Baldwin balanced type is placed in the main dome, and

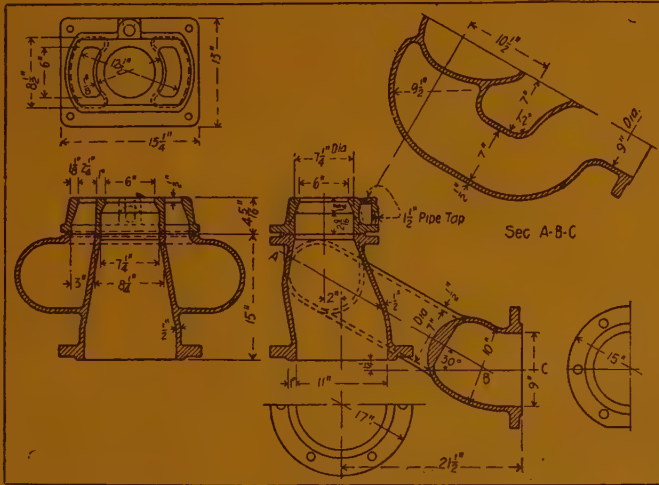


Fig. 4. — Exhaust stand and nozzle used on converted simple articulated locomotives of Great Northern Railway.

is connected with the superheater header in the smokebox by means of an internal dry pipe. The steam pipes leading from the superheater header terminate in a second header, placed transversely in the bottom of the smokebox and having connections with two outside steam pipes which lead back to the rear cylinders. The front cylinders receive their steam supply through a centrally located pipe connected to the same header, and having three ball joints. All slip and ball joints are lubricated. Oil cups are used on all packings.

The exhaust from the two front cylinders is conveyed to the nozzle through a pipe placed on the center line, and fitted with two ball joints lubricated with

oil, and one slip joint lubricated with grease. The exhaust pipe from the rear cylinders is placed on the left side, and terminates in an annular opening surrounding the exhaust nozzle of the front cylinders (fig. 4).

The steam supply for the Elesco exhaust steam injector is taken from the exhaust pipes of both the front and rear cylinders. This injector is placed under the cab, on the right side.

The frames are six inches wide, spaced 41 inches apart transversely. Special attention has been given to the design of the articulated frame connection. The vertical hinge pin is six inches in diameter, and is held rigidly in the rear cylinder saddle, being secured from turn-

ing by a tapered fit and a heavy tapered key. The saddle is bushed and the pin is case-hardened. By holding the pin rigid, the wear is taken by the bushed connecting bar, which can be easily re-bushed; and thus the slack between the two units can be kept at a minimum. Both the vertical and horizontal hinge pins are internally lubricated with grease, which is applied from an easily accessible outside location.

The four cylinders are cast iron and are interchangeable, as are also the front and back pistons, crossheads and connecting rods. Corresponding crank pins, wheels and axles in the front and rear units interchange also. Steam distribution is controlled by 14-inch piston valves operated by the Walschaerts valve gear. A Ragonnet type B power reverse mechanism is applied. The reach rod connecting the front and back reverse shafts is placed on the center line of the locomotive, with its joint immediately above the articulated frame connection. In this way there is practically no distortion to the movement of the forward valves when the locomotive is traversing a curve. The valves have 1 7/8-inches steam lap and no exhaust clearance, and are set with a travel of 6 3/4 inches and a lead of 3/16 inch. The cut-off, when working in full gear, is 65 %.

The piston heads are steel of the solid type fitted with bull rings and packing rings of Baldwin special iron. The main crank pins are of vanadium steel, hollow bored. With the exception of the front main rod stubs, solid end stubs with floating bushings are used throughout. All the pins are lubricated with grease.

The boiler is supported on the front frames by means of a single bearer, located to give an even weight distribution and designed to distribute the load on the frames with a minimum frame stress. A low bearing pressure per square inch is assured by the liberal bearing area provided, and the bearer is designed to permit a rocking movement of the frames

without binding. No centering device is applied, experience having proved that its use is unnecessary. The upper castings of the bearer and of the rear cylinder saddle are riveted to the boiler, the liners being placed outside the shell. The forward equalization divides between the second and third pairs of drivers, thus giving a three-point suspension for the front unit.

The front and rear trucks are in many respects similar in construction, and have interchangeable wheels and axles. The front truck is center bearing and the rear truck side bearing, the bolsters in each case being suspended on heart shaped links. The transverse distance between the inside faces of the truck tires is 53 1/4 inches, while for the driving tires it is respectively 53, 53 3/8, 53 1/4 and 53 1/8 inches for the first, second, third and fourth pairs of drivers of each group. Flanged tires are used on all the wheels.

The cab is located sufficiently far back to place all flexible stay-bolts outside, where they are easily accessible. To provide clear vision for the enginemen, the front cab windows are placed in specially designed brass frames which permit the glass to extend the full width of the front panels. Steam piping immediately forward of the cab is placed under the jacket; and this, with the downward trend of the running boards as they extend forward and the arrangement of all external fittings, gives the engine crew as clear a vision as can be obtained in a locomotive of this size and type.

These locomotives are equipped with force feed lubricators for the front cylinders, and with flange oilers on the leading drivers of both the front and back units. A drifting valve with handle conveniently located in the cab, and having a 2 1/2-inch pipe connection to the steam valve stand, supplies steam to the cylinders when drifting. The main steam valve stand is placed on the roof sheet in front of the cab, and there is also an auxi-

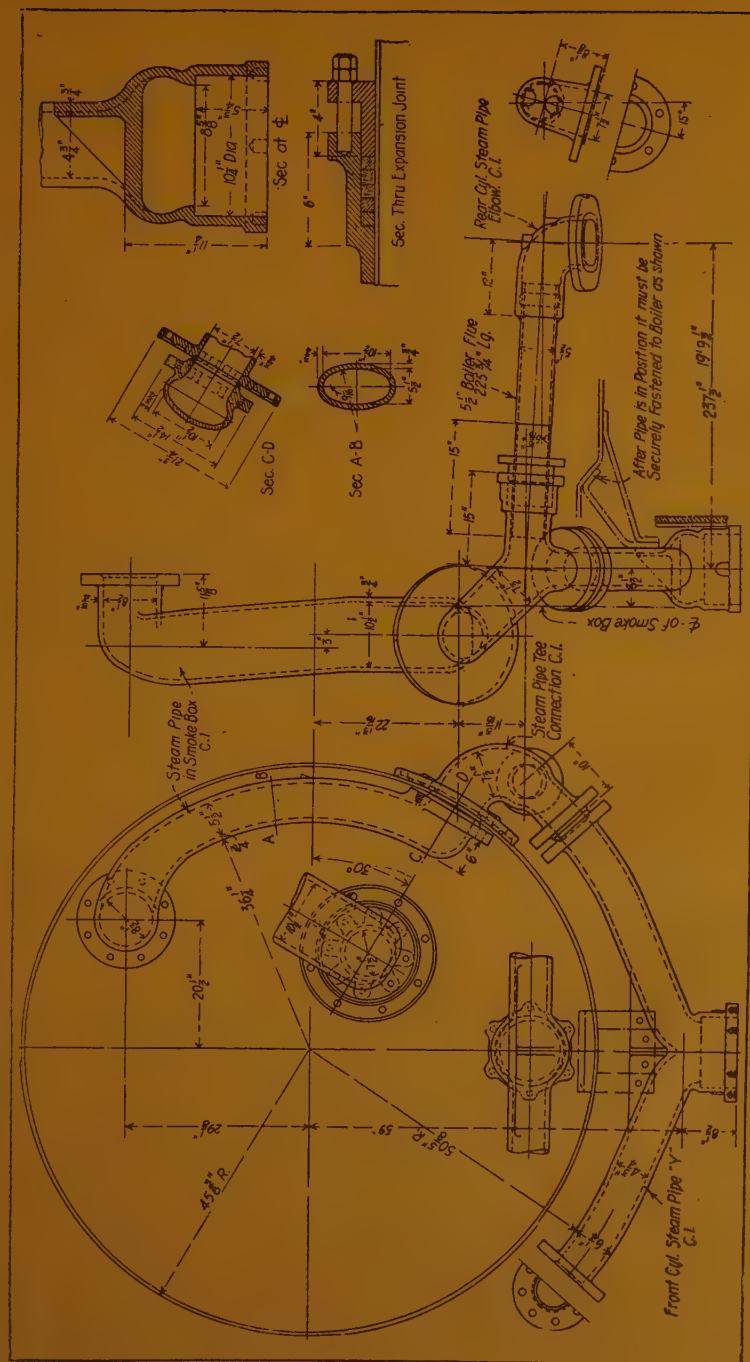


Fig. 5. — Steam and exhaust pipe arrangement used by Great Northern Railway on *Mallet* compound locomotives converted into simple articulated engines.

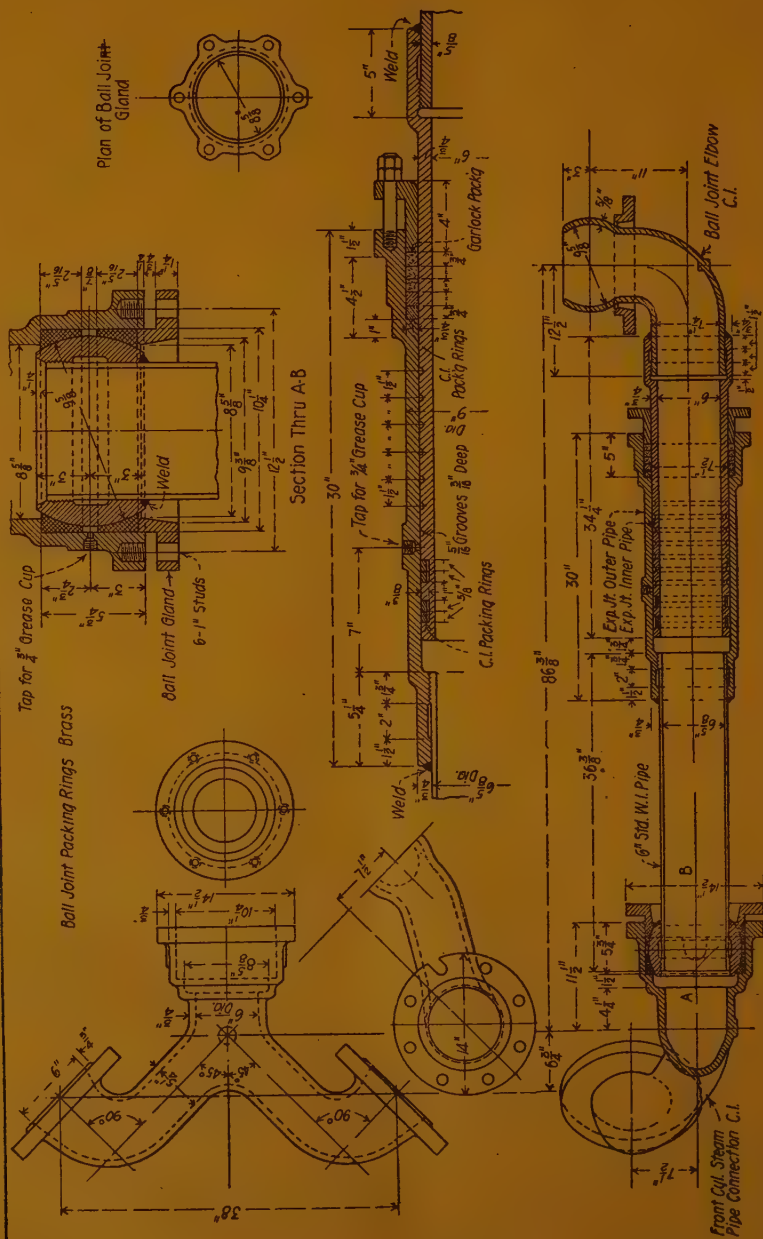


Fig. 6. — Details of steam and exhaust pipe construction used by Great Northern Railway on converted simple articulated locomotives.

liary steam manifold on the left side of the back head connected to the steam valve stand and serving the blower in the smokebox, the oil atomizer tank heater, cab heater, sprinkler, flange lubricator heater and force feed lubricator heater. On the right side of the back head is an air manifold, with valves serving the bell ringer, sanders, cylinder cocks for the front and back units. This manifold also has

plugged connections for the fire door, tube cleaner, and whistle.

The oil burning arrangement has a number of interesting features. The damper controlling the intake of air through the fire pan is automatic in its action, opening by draft and closing by gravity. The fire door is provided with an intake riser through the deck, thus preventing cold air from being drawn into the cab.

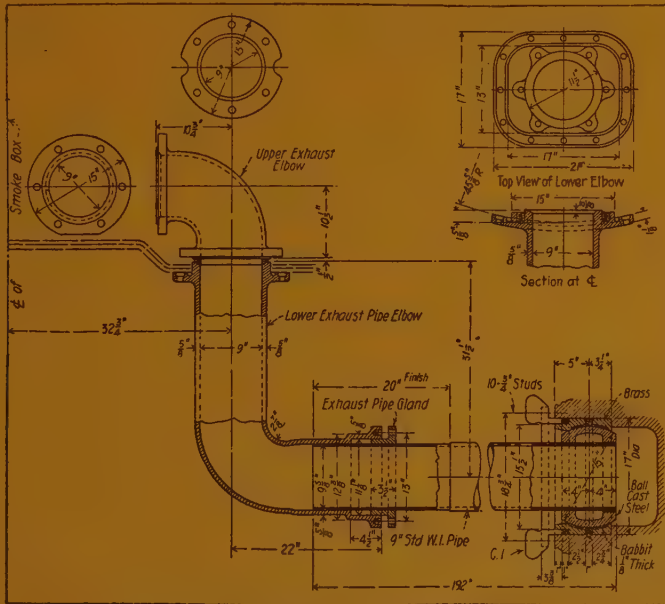


Fig. 7. — Details of exhaust pipe construction used by Great Northern on converted simple articulated locomotives.

The firebox has a brick flash wall in the back, and all firebox seams are protected from the direct action of the fire by seam fire brick.

In order to prevent the exhaust from the air compressors from drawing on the fire when drifting down long grades, the compressors discharge into a separate header, which provides an atmospheric exhaust.

The tender of this locomotive is carried on two Commonwealth cast steel

trucks of the six-wheeled equalized type. The frame is a one-piece, Commonwealth steel casting. The tender is built with a stoker conveyor trough, in view of the possibility of changing to coal burning in the future. A pilot is placed at the rear end. With capacity for 16 800 gallons of water and 5 800 gallons of oil, these tenders rank among the largest thus far built.

These locomotives have a height over all of 16 ft. 1 in. and a maximum width

of 11 ft. 3 in. The length measured from the face of the engine front bumper to that of the tender rear bumpers is 107 ft. 2 1/4 in. Further particulars are given in the table of dimensions.

Principal weights proportions and dimensions of Great Northern Railway 2-8-8-2 simple articulated locomotives.

Service	Freight.	Journals :	
Type, single expansion	2-8-8-2.	Main, diameter and length.	12 1/2 in. by 16 in.
Fuel	Oil.	Others, diameter and length.	11 in. by 14 in.
Cylinders, four.	28 inches by 32 inches.	Truck Wheels :	
Valves, piston, diameter.	14 inches.	Leading, diameter.	33 inches.
Boiler :		Trailing, diameter.	33 —
Type	Conical.	Truck journals :	
Diameter.	100 inches.	Leading, diameter and length.	6 1/2 in. by 12 in.
Working pressure.	210 lb.	Trailing, diameter and length.	6 1/2 in. by 12 in.
Firebox :		Wheel bases :	
Material	Steel.	Driving	43 ft. 7 in.
Staying	Belpaire.	Rigid	16 ft. 6 in.
Length	144 inches.	Total engine.	58 ft. 2 in.
Width.	108 —	Total engine and tender	96 ft. 3 1/2 in.
Depth, front.	93 —	Total length, over all	107 ft. 2 1/4 in.
Depth, back.	75 1/4 inches.	Weights, in working order :	
Tubes, number and diameter	310—2 1/4 inches.	On driving wheels	532 800 lb.
Flues, number and diameter	68—5 1/2 —	On front truck	37 550 lb.
Length, tubes and flues	24 feet.	On back truck	24 590 lb.
Heating surfaces :		Total engine	594 940 lb.
Firebox	272 square feet.	Total engine and tender	916 500 lb.
Combustion chamber	160 —	Tender :	
Tubes and flues.	6 710 —	Wheels, number	12.
Total	7 142 —	Wheels, diameter	33 inches.
Superheating	1 896 —	Journals	6 1/2 inches by 12 inches.
Comb. evap. and superheat	9 036 —	Capacity, oil.	5 800 gallons.
Grate area	1 408 —	Capacity, water.	10 500 —
Driving wheels :		Tractive force	127 500 lb.
Diameter outside	63 inches.		
Diameter center	56 —		

Inspection of flexible staybolts, ⁽¹⁾

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Figs. 1 to 4, pp. 527 and 528.

(Railway Mechanical Engineer.)

The development of the flexible staybolt, in this country, dates back to about 1890 and early experimentation was stimulated by the enormous number of breakages which occurred in the rigid type of staybolt. Probably the first type of flexible staybolt which could be readily inspected without removal was one of the round headed design, using a sleeve and removable cap, which was designed by John B. Tate of the Pennsylvania Railroad and introduced by the Flannery Bolt Company about 1904. This design gave promise of eliminating many of the weaknesses of former types and provided a means, though an expensive one, of ascertaining the condition of the bolt without removing it from the boiler. For these reasons it was quite generally tried out by many railroads and the results obtained were so satisfactory that its adoption and general use almost immediately followed.

In 1905 a Committee of the American Railway Association reporting on flexible staybolts said of it: « Though of comparatively recent date, it has been received with great favor, indicating the rapidity with which a new bolt of promising design is given a practical trial in the effort to cure the staybolt trouble. » Further in this same report the committee stated the following: « A simple means of positively detecting cracked and bro-

ken bolts is an improvement needed by all flexible bolts that are in service at the present time. The removal of the cap, which will allow an examination of the bolt, is the only absolute means possible with flexible bolts of the present design. »

In 1911 the act commonly known as the Locomotive Boiler Inspection Law became effective, under authority of which, rules requiring among other things the removal of caps from flexible staybolts for inspection purposes at special stated intervals, were promulgated and enforced.

The generally satisfactory service rendered and the very small percentage of breakage to total number in service (this type having become practically standard) created a doubt in the minds of many railroad mechanical officers of the justification of such a rule or requirement and it was quite generally, and for a time quite strenuously, opposed. However, the Locomotive Inspection Bureau, through its corps of inspectors, had indisputable evidence of the necessity for thorough and regular inspection, for while it was admitted that the percentage of breakage to the total number in service was small, it was shown beyond question of doubt that in certain instances breakage did occur to such an extent as to become a menace to life and property.

⁽¹⁾ Abstract of a paper presented at a meeting of the Southern Railway Club, Atlanta Ga., 17 September 1925.

Investigations were begun to determine the cause of breakage in an endeavor to apply a remedy. A number of investigations confirmed the absolute necessity for careful and frequent inspections and also clearly demonstrated the need of a more accurate and positive method of test than the mere removal of the caps and an examination of the bolt heads.

Instances were found where, under bad water conditions, accumulations of scale between the body of the bolt and the inner wall of the sleeve were such as to solidly lock the bolt in the sleeve. The result was to render ineffectual the flexible feature and to cause the bolt to break at the fire box sheet.

During the past ten years, and more diligently during the past five years, after these abnormal conditions had been prominently developed, constant effort has been made to perfect a method of inspection that would provide greater safety and insure against loss of life, injury to persons, and damage to property.

The first actual service test of such a method was made in August 1920 on large Mallet type locomotives where abnormal conditions existed and where breakage of flexible bolts was excessive. This method consisted of the installation of flexible bolts with telltale holes extending from the firebox end entirely through the body section and terminating within the bolt head, and the testing of these bolts at regular intervals with a specially constructed instrument to determine definitely that the telltale holes were open and, therefore, operative throughout their entire length. This was accomplished by so constructing the instrument that an electrical circuit would be established when contact was made at the end of telltale hole.

During this service test, two distinct features were developed :

First. — that moisture, due to temperature changes, condensed in the telltale hole and formed rust or iron oxide which

gradually increased to such an extent as to interfere with the insertion of the testing instrument. In seeking a remedy for this condition, various methods were tried, the most satisfactory and the one at present in use being the electro-plating of the walls of the telltale hole with copper. Four years experimental work and service tests have demonstrated the complete success of eliminating the difficulty by this method.

Second — that cinder and other foreign matter accumulated in the telltale holes to such an extent as to require excessive labor to dislodge and remove it in order to permit the insertion of the testing instrument. The cost and time required for this made the method impractical. After numerous experiments it was found that a closure of fire-proof porous material applied in the end of the telltale hole prevented the accumulation and at the same time permitted leakage of steam or water in case of fracture, and that it was also readily and cheaply removable to allow insertion of the testing instrument.

Application of telltale flexible staybolts.

The telltale flexible bolt is identically the same as the Tate bolt with the addition of a telltale hole extending through the entire length of the body section and terminating within the head of the bolt. The walls of the telltale hole are copper plated to prevent rust or corrosion within the hole and to prevent them from becoming closed from this cause.

They are applied exactly the same as the ordinary flexible bolt. If the method of riveting closes the end of the hole, it may easily and quickly be re-opened, after which a porous fireproof closure is applied that will prevent the accumulation of foreign matter from entering the telltale hole and that will permit leakage of steam or water in case of a break or fracture, which serves as a daily indicator of the condition of the bolt.

Inspection of telltale flexible staybolts.

In addition to depending on the leakage through the telltale hole, an inexpensive method of periodically checking up the condition of the telltale hole is provided as follows :

The fireproof porous closure is first removed, after which the specially constructed testing instrument is inserted. Upon reaching the extreme end of the telltale hole and making contact therewith, a light flashes in the handle of the tester indicating that the hole is open and therefore operative throughout its entire length.

The method of testing has been built upon the fact that a broken bolt having

a telltale hole will show leakage of water or steam, providing the telltale hole is open and operative and that it extends to every breakable part of the bolt.

The tester is so designed and constructed that it will positively indicate whether or not the telltale holes are open throughout their entire length. After inserting the tester in each telltale hole and securing light in the handle (which indicates that contact has been made with the extreme inner end of the hole) if the bolt is broken, or fractured into the hole, leakage will positively occur when water pressure is applied to the boiler.

Use of the tester.

First, with a sharp pointed pin or punch and a light hammer, break through the porous closure; then blow all of the remaining particles out of the telltale hole with the air tool — shown in figure 1. Attach the ground connection in any convenient telltale hole, then insert the tester rod into each telltale hole until contact with the end of each hole is secured. Such contact is indicated by the lighting of the bulb in the tester handle, as shown in figure 2. After con-



Fig. 1. — Cleaning out the telltale hole by means of special air tool.



Fig. 2. — A light in the tester handle indicates that the telltale hole is open the full length.

tact, has been secured in every bolt, apply water pressure to the boiler and every defective bolt will be indicated by leakage through the telltale hole. If no defective bolts are found, or after replacing any that are found, again close the telltale hole with the fireproof porous material and the locomotive is ready for service.

Cases may occur where breakage or fracture will be indicated by leakage and will not be observed or detected at the time they develop, as for instance bolts in locomotives in pusher service at isolated points or bolts located behind brick arches, grate bars, etc., and in which the telltale hole will gradually become filled by accumulation of scale from the boiler water. Therefore, whenever the tester is inserted, it strikes an obstruction and fails to show a light in the handle, as is shown in figure 3. In such cases the tester should be removed and a special cleaning drill applied to remove the obstruction. After drilling, blow clean with the air tool such as was shown in figure 1, re-insert the tester, and if the

hole has been thoroughly cleaned, contact will be secured and indicated by the lighting of the bulb as before described and when water pressure is applied, leakage will occur.

Bear in mind that securing contact in the telltale hole does not indicate that the bolt is in good condition, but only that the telltale hole is open and operative throughout its entire length. It is the failure of the bolt to leak under pressure after contact has been obtained which indicates that it is not broken.

The present method of inspection requires from three to four or more days, the principal part of the work being the removal and replacement of parts, rather than the actual time required by the inspector to examine the bolts.

By the new method herein described, it is not necessary to touch or remove anything on the outside of the boiler and the entire test on a modern locomotive boiler containing a full installation of



Fig. 3. — An obstruction in the telltale hole prevents the tester rod from making contact. This condition is indicated by the failure of test lamp to light.



Fig. 4.
Applying the porous closure to telltale hole after inspection.

flexible bolts can be completed within an eight-hour day — and at a labor cost of from \$10 to \$20, depending on the size of each respective installation.

The cost to strip, remove caps, inspect, and replace runs from \$100 to \$250, depending upon the size of the locomotive and upon the facilities at hand, and in addition, results in two, three, and sometimes more, days loss of engine service.

The principal advantages of the new method of inspection are: Greater safety by constant daily indication of bolt conditions; material reduction in maintenance costs by reason of eliminating a vast amount of labor now required under the older method of inspection, and a substantial saving in locomotive service by reason of being able to make inspection by the new method at the time of the regular annual hydrostatic test and without additional loss of locomotive service.

A number of railroads have been using the new method of inspection just described for some time, irrespective of the fact that the Government had not yet approved it, because they were convinced that it added such an immeasurably increased factor of safety that it would more than compensate for the additional cost of this method of testing in addition to complying with the Interstate Commerce Commission rules that require the removal of caps every two years. The Locomotion Inspection Bureau, however, has been fully aware of the use of this new method for the last four or five years, has been checking up the results carefully, and when a number of the railroads that have been using this method of inspection for some time made an application for a modification of Rule 23, careful consideration was given with the result that, at a general session of the Interstate Commerce Commission held at its office in Washington on 26 July, 1925, it was ordered that Rule 23, as approved in the order of the Commission

entered 7 April, 1919, be, and the same is hereby amended to read as follows:

« 23. *Method of testing flexible staybolts with caps.*

« Except as provided in paragraph (b), all staybolts having caps over the outer ends shall have the caps removed at least once every two years and the bolts and sleeves examined for breakage. Each time the hydrostatic test is applied, the hammer test required by rules 21 and 22 shall be made while the boiler is under hydrostatic pressure not less than the allowed working pressure.

« (b) When all flexible staybolts with which any boiler is equipped are provided with a telltale hole not less than 3/16 inch nor more than 7/32 inch in diameter, extending the entire length of the bolt and into the head not less than one-third of its diameter and these holes are protected from becoming closed by rust and corrosion by copper plating or other approved method, and are opened and tested, each time the hydrostatic test is applied, with an electrical or other instrument approved by the Bureau of Locomotive Inspection, that will positively indicate when the telltale holes are open their entire length, the caps will not be required to be removed. When this test is completed, the hydrostatic test must be applied and all staybolts removed which show leakage through the telltale holes.

« The inner ends of the telltale holes must be kept closed with a fireproof porous material that will exclude foreign matter and permit leakage of steam or water, if the bolt is broken or fractured, into the telltale hole. When this test is completed, the ends of the telltale holes shall be closed with material of different color than that removed and a record kept of colors used.

« (c) The removal of flexible staybolt caps and other tests shall be reported on

the report of inspection Form No. 3, and a proper record kept in the office of the railroad company of the inspections and tests made.

« (d) Fire box sheets must be carefully examined at least once every month for mud burn, bulging, and broken staybolts.

« (e) Staybolt caps shall be removed or any of the above tests made whenever the United States inspector or the railroad company's inspector considers it desirable in order to thoroughly determine the condition of staybolts or staybolt sleeves. »

[625. 258 (.4) & 656 .259 (.4)]

Car retarders used in Europe.

Figs. 1 to 7, pp. 531 to 534.

(*Railway Age.*)

A system of rail brakes or car retarders for automatically controlling the speed of cars in hump yard switching has been developed in Germany and was first installed at Oberhausen in 1918. Other installations have been made during the last three years at Cologne, Seddin, Schwelgren and at several other important yards on the German State Railways. This system, which is known as the Froelich hydraulic system, has also been installed at Aarhus, Denmark, and Susteren, Holland. The illustrations show the apparatus installed at Aarhus.

The design of the apparatus employed, to which the term rail brakes is applied, is based on the invention of Dr. Froelich, railway superintendent to the German Government. The W. Dederich, Ltd., London, England, holds the right for the sale and installation of the Froelich hydraulic system in all parts of the world except Germany. The purpose of the system is to eliminate the necessity for employing car riders—a brakeman on each cut of cars. The manual braking of cars on humps is in many cases unsatisfactory, resulting in damage to cars and lading and also in serious injury to employees, especially in stormy weather ⁽¹⁾.

In the Froelich system a long brake shoe made of a rail, lying along each side of the running rail of the track, is operated by hydraulic pressure to bear against the flanges of passing car wheels. The operator in the tower, being informed by automatic track scales of the weight of a car, can estimate its probable momentum and operate the car retarder to reduce the speed so that the car will run into the proper track and come to a stop without bumping other cars so hard as to cause damage.

Weight of car effects braking automatically.

In the mechanisms first devised in Germany the bearing blocks were primarily raised and depressed mechanically, every subsequent operation being carried out by hydraulic power. In later installations, such as that at Seddin, the entire movement is operated hydraulically. Another unique feature of this system is that the weight of the car auto-

diana Harbor Belt Line., published in the *Railway Age* of 15 November 1924, page 895, and 9 May 1925, page 1143. A brief description of the Froelich apparatus was given in the *Railway Age* of 6 December, 1924, page 1038.

See also *Bulletin of the International Railway Congress Association*, January 1926, pp. 5 and 11.

(1) The economic aspect of car retarder systems was described in detail in connection with two articles concerning car retarders installed on the In-



Fig. 4. — The hump, the rail brake and the tower in the yard at Aarhus, Denmark.



Fig. 3. — Rail brake as installed at Aarhus, Denmark.



Fig. 2. — Automatic switch control box with the collector in place.

matically establishes and controls the braking effect while the car is passing through the car retarder.

These brake rails *a* (see diagram) are mounted on the brackets *b*, which latter rest with a sliding contact on the vertically adjustable bearing blocks or supporting beams *c*, those on the inner side carrying the inside brake rails *e* pivoted at *d* on brackets *b*. With these in the elevated position the wheels of the train run with their flanges bearing on the base of

the brake rails *e*, forcing the latter downward, and hence each pair of brake rails presses against the lateral surface of the wheels or tire sides so that the more the bearing blocks are forced upward the greater this pressure becomes. Lack of uniformity in the thickness of the wheels has little effect on the action of the rail brakes. The number of axles, also, has no influence on the braking efficiency, which does not, as in the case of hand braking, fall as the number of axles increases.

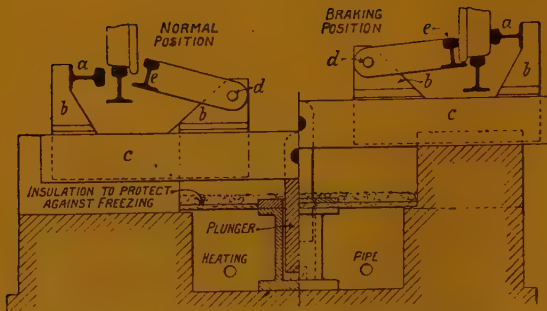


Fig. 4. — Section of rail brake apparatus.

- a* = Brake rails.
- b* = Brackets.
- c* = Supporting beam.
- d* = Pivots.
- e* = Inside braking rail

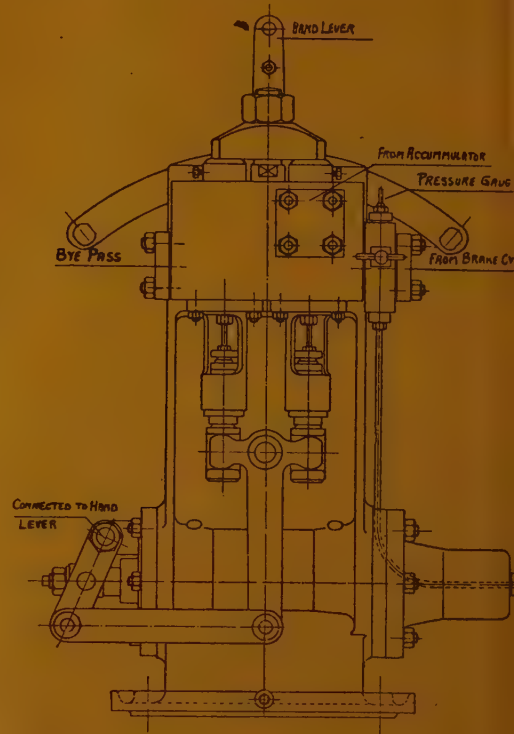


Fig. 5. — Valve assembly unit which controls the hydraulic pressure.

A determining factor in the force of braking is the weight of the car itself. The apparatus is generally designed so as to make the pressure against the wheel

four times that of the hydraulic pressure. The latter is regulated by a valve which holds the pressure automatically, the pointers indicating the exact point at

which the wheels enter the brake, thereby sending up the pressure which is instantaneously reduced to the predetermined maximum allowed by the valve. If the operator, through lack of skill, employs too high a pressure, the car is simply lifted off the track by a fraction of an inch and the excess hydraulic pressure is taken up by the automatically-acting compensating device, which is set to function at a given pressure. Although rarely occurring in actual practice, and only because of gross negligence on the part of the operator, it can happen in this way that the braking effect will be reduced automatically to zero at the instant the car begins to climb, *i. e.*, to leave the foot of the inner brake rail. In this manner the valve merely maintains under all conditions the maximum hydraulic brake pressure which is determined by the position of the hand lever in the operator's cabin. From this it follows that violent braking is out of the question. With this feature, combined with the permanently parallel position of the brake rails, there is no possibility of derailment.

From the foregoing it will be understood that a given hydraulic pressure corresponds to a certain rail brake pressure, which in its turn is dependent on the axle loads, and is also governed by a special automatic by-pass device. The correlation between these two pressures has been utilized to compile the figures for varying weather conditions, as a certain pressure always corresponds to certain work. From this, a scale has been prepared which is fitted on the lever quadrant, indicating the exact position of the lever to enable the operator to apply the requisite amount of braking force if he knows the weight of the car and the distance it has to run.

How the operator is informed of the weight of a car.

In order to inform the operator of the weight of the car a special weighing de-

vice has been devised. This records the axle loads in four different steps and transmits the information to an indicator board (placed within sight of the operator), just before the car enters the brake and while it remains therein. In this way the operator sees the weight of each car before applying the brake. He knows into which track the car is to run, and he can also see what cars are already in each one, so that he is in a position to determine the braking effect required in accordance with the scale given in the table already mentioned. Practice enables the operator to judge to a nicety the amount of brake force to be applied to the cars so as to give them just enough impetus to reach the last preceding car without bumping against it.

After a little practice he becomes expert in his work and is independent of the table, this latter finally representing nothing more to him than a means of making rough adjustments. He will then rely preferably on his own observation of the behavior of the car, before and after braking, to gage the lever manipulation required to bring about the desired result. The brake is released by dropping the transverse members.

The hydraulic power is supplied by a plant of any approved design and is required solely for raising the brake initially, for making up by-pass losses, and for otherwise furnishing additional pressure when needed. In order to obviate the risk of the water in the hydraulic system freezing in severe weather the pipes outside the control station are embedded a sufficient depth to prevent the penetration of frost while heat is supplied to the braking conduit, this heat being derived from the same source as that which supplies the heating requirements of the control station or switchman's cabin. The water is supplied by a compressor pump driven by an electric motor and collected in a hydraulically-controlled reservoir, suitable valves actuated by a simple lever regulating the water level.

The use of well designed rail brakes in hump yards enables a considerable saving to be effected in personnel, in the wear and tear of rolling stock, and also

as regards reliability and the expeditious handling of trains. In order to obtain the best results it is desirable that the working of the switches and that of the

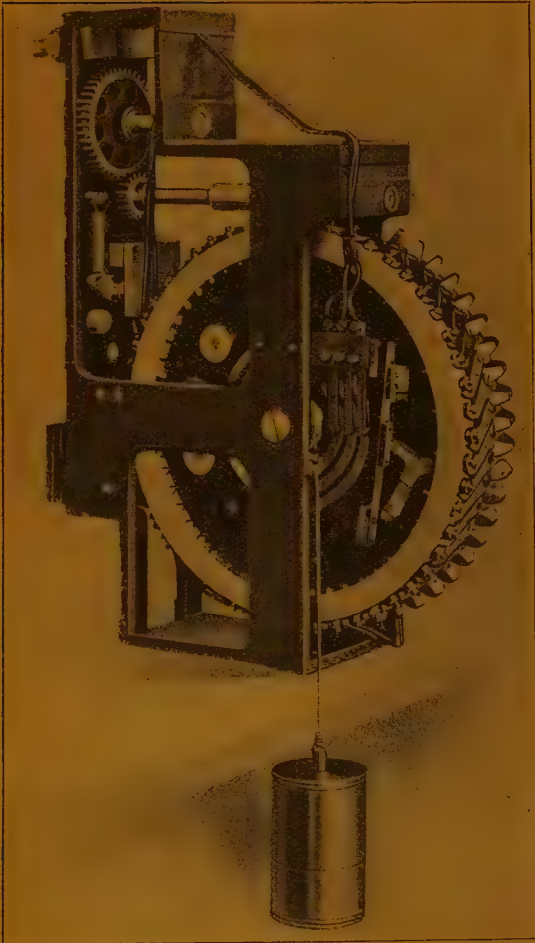


Fig. 6. — The collector drum controls the operation of the switches.

brake should be under the same control, thus eliminating disadvantages arising through several switchmen having to work strictly in accord with each other's movements. Apart from the fact that



Fig. 7 — The master control unit located in the tower

the brake operator and the switchman work to the same instructions and have to make the same observations, the work of the one is interdependent with the work of the other, especially if irregu-

larities should occur in the passage of the cars over the hump. Unskilful braking may interfere with the movement of the switches. Changes in the destination of the cars (into a track other than that originally intended) may call for a different brake application. Further, provision has to be made for the carrying out of operations in foggy weather.

A system of power switch machines has been designed and is being used in Germany in conjunction with the Froelich rail system. This is the collector drum system of the General Electric Company (England). It is distinguished from others used for switch operation through having not only one, but as many as 50 contacts, mounted on a common drum corresponding to 50 different point positions for as many switching tracks leading from the hump. The manipulation of a lever actuates one contact and simultaneously turns the drum mechanically, so that at the next lever movement the contact next following is brought into action.

Concentrically inside the contact drum, but rotating independently of it, is another drum carrying a magnet which is supplied with current from an insulated rail placed in front of the rail brake, or it may be controlled from a rail contact. This magnet prepares the connecting-up of the contacts which, however, only takes place after the car has left the insulated rail. In passing off the car releases the magnet and allows the inner drum to establish contact with the next position. In this manner the switching program for 50 cars, or cuts of cars, can be collectively set in advance on any one track by means of a single controlling mechanism, and shifted in rotation as the cars descend the hump. This feature renders the operation independent as regards the time required for a car to run down the hump. The automatic switch box with the « collector » in position, is shown in one of the illustrations. It will be understood that the controlling device enables each cut of cars to shift the

switches for its successor. Through this collective setting of all the switches in advance by one mechanical operation the amount of work to be done is materially reduced, and can, in fact, be carried out by one man. A pointer advances automatically down the list of cars of which the train is composed, and shows the switchman at any moment exactly how far the work has progressed and which car is passing at the time. Another pointer on the opposite side indicates automatically for how many cars or cuts of cars the switches have been shifted in advance. As soon as the two meet the collector is « empty », so to speak, and ready to receive switch positions for another 50 cars. A bell rings when the third car from the last passes through the first switch on its run, or in case of a fault in the control circuit.

To provide for cases where it becomes necessary to interfere with the anticipated setting of the switches, or where the instructions as to the destination of certain cars are changed while the switching is in progress, the operator is provided with a diagrammatic view of the track. On this board the switches are provided with buttons and with small lamps which are included in the track circuit and which glow as long as a car is on the insulated rail. By pressing these buttons it is possible to change the switch positions which had previously been selected for the collector. By means of a special switch all contacts in the collector drum can be put back into neutral. In this way emergencies have been provided for. With the small lamps on the track plan the operation of the hump yards is facilitated under unfavorable weather conditions. Thus, the passage of the cars into the classification tracks is, in the first place, indicated by the advance of the pointer on the list of cars in front of the switchman, and checked for a second time by the glowing of the lamps on the board as the car reaches the first switch on its run. Finally the switchman can throw each switch by

hand, if he so desires, without impeding the accurate functioning of the switch boxes, the collector or the drums. The latter are independent of each other, and for this reason, though one or the other may get out of order, the complete plant can never do so.

Example of yard operation

The following example will show how a certain classification yard is being operated mechanically by centralized control. The drawing (fig. 1) represents the type of gravity yard having level receiving tracks. Track and profile plans, as well as the position of the rail brakes, have been made as nearly correct theoretically as local conditions permit. Accordingly four rail brakes 65 feet in length each were thought desirable for reasons of reliability. Over 4 000 cars had to be classified daily and if four brakes were installed the failure of one would be felt less than if a smaller number were used. Besides, a multiplicity of brakes is conducive to a better development of the layout of the switches and the attainment of « a short braking zone ». Just below the summit of the hump two rail brakes 11 ft. 6 in. long have been installed. These are called summit, or primary, brakes, and serve the purpose of retarding a car temporarily, but the braking effort may be made such as to bring the whole train to a standstill. The operator

faces the hump and has on either side of him one common valve for the summit brakes. The same room overlooking the sorting sidings accommodates the control switches, and the apparatus for working and supervising the switching as described above. A loud speaker has been arranged which communicates with the men at the hump summit and at the entrance to the classification tracks. Finally, a button for sounding horns between the sidings, and a lever for giving signals to the engineman, have been conveniently arranged.

The mechanism for throwing the switches is installed on the floor below, and the power plant is in the basement. For the sake of reliability both pumps and motors are provided in duplicate, one being electrically, and the other gasoline driven. If the electric current should fail both motors can drive one pump or the other as may be required. The highest possible degree of working reliability has been attained, as the brake valves can be replaced within a minute or two. The operator's cabin and the rail brakes are centrally heated from the basement. Apart from the brake operator and the switchmen, one man is needed to uncouple the cars at the summit of the hump, and one man for each five to eight classification tracks. One of these men has to remain in the vicinity of the loud speaker and the others are stationed at various points throughout the yard.

[515 .585 & 585 .415]

Composition and character of railway operating expenditure,

By ALFRED WALTHER,
CERTIFICATED ENGINEER, ZURICH.

Figs. 1 to 7, pp. 539 to 550.

(*Schweizerische Bauzeitung*.)

By the « Character Expenditure » we mean its relationship to a varying degree of business activity. In the article

entitled : « Principles of the science of Industrial Costs » published in the *Schweizerische Bauzeitung* of April-

May 1923, we have endeavoured to define the problem presented by the degree of activity in its relation to certain costs and to formulate the fundamental bases, intentionally avoiding the investigation of any special cases because we wish to give a general idea of this complicated subject which has been little investigated up to the present, in order that we may prepare the way for further researches. We note with pleasure that our first effort has been received by many, at least abroad, with appreciation. It has been recognized that the present method of dealing with expenses, which is limited to the exact distribution of the costs of production between the various products of an industrial undertaking, is not sufficient to solve many important questions, and particularly those concerned with the policy of price fixing. « The appreciation of this shortcoming » writes the *Director General*, Mr. Herbert Peiser (1), has « led to a new method which endeavours to calculate the costs of production as a function of the varying degree of business activity, starting from the conviction that it is only by a careful study of these relationships that one can arrive at a policy of governing prices and transactions profitable both to the individual enterprise and to the whole community. Every complete investigation shows that this method opens out new vistas of a peculiarly interesting character which may perhaps prove able to include progressively the whole problem of industrial costing ». At present we are only at the commencement of this evolution and it will now be necessary to make special intensive researches into the most diverse branches of industry, in order to collect the necessary material

for the final development of the general theory at present in its initial phase.

Peiser, in his book that we have just mentioned, has analysed the composition and the character of the costs of a steam generating station; in a recent article (1) he attacks the problem of the relation of costs to the degree of activity of trade from the economic point of view taking the work of Ford as his basis.

We shall now proceed to examine the general theory for a particular case, that of railway costs, and by pointing out some interesting features of the various expenditures that make up these costs, show how the theory can be applied to them.

I. — The influence of electrification on the character of the cost of traction on the Swiss Federal Railways.

The General Management of the Swiss Federal Railways presented a report, on the 30 June 1924, to its administrative Council on « the comparative cost of electric and steam traction » which contains extremely interesting and instructive figures concerning the relationship between railway expenditure and the varying degree of activity of trade. This report was published in the *Schweizerische Bauzeitung* and Professor Dr. W. Kummer gave an analysis of it in the issue of this journal of the 25 October 1924, taking up, it is true, a quite different point of view. We can therefore refer the reader to his article and avoid reproducing and making comment on the numerical basis of our investigation.

The figures appearing in the report just mentioned only serve, in fact, as a means of determining the « equivalent cost of coal » and enable us, by making

(1) H. PEISER : *Der Einfluss des Beschäftigungsgrades auf die industrielle Kostenentwicklung* (The influence of the degree of activity on the rise of industrial costs. — Julius Springer, Berlin 1924).

(1) H. PEISER : *Fragen zur Produktionssteigerung im Lichte Ford'scher Ziffern* (Questions of increase of production examined in the light of figures supplied by Ford) (*Technik und Wirtschaft*, February 1925).

a few auxiliary hypotheses to show the total costs of traction in the form of a graphical diagram which gives information from several points of view and also an idea of the composition and growth in the costs of both steam and electric traction.

We shall first consider the *fixed charges, those independent of the degree of activity* of trade; under this heading, interest and maintenance (redemption and renewal) of capital take a high place in the case of electric traction where $g_e = 42\,720\,000$ fr. (Swiss) per annum, whereas in the case of steam traction the corresponding expenditure, including the small difference due to the higher cost of maintenance of the track, only attains the figure $g_s = 4\,875\,000$ fr. (Swiss). The cost of running and maintenance of the whole of the electric installations amounts to $a_e = 4\,376\,000$ fr. (Swiss). These costs also may be considered as being in the main independent of the degree of activity of transport. There is no similar entry in the account in the case of steam traction.

The costs of driving and maintenance of the motor vehicles c_k and c_n , as well as the other costs which we have yet to mention, are a *function of the degree of activity* of trade expressed in the report of the General Management in gross ton-kilometres and in train-kilometres. Unfortunately the report gives no direct information as to the form of the curve of costs that corresponds to an increasing activity; it only considers a single degree of activity definitely given as 9 200 millions of gross ton-kilometres 5 600 millions of gross ton-miles (traffic during the year 1913). We are accordingly forced to proceed on our own account to an estimation of these costs and we do not think that we have made any error in assuming that they do not pass through zero, but are composed in part of a constant quantity and in part of one increasing in a constant ratio, because however low the activity may fall, the

costs will be large, if only because a large number of the trains must always be run whether empty or otherwise. Let us suppose, as a rough approximation, that about 70 % of the costs in question are constant and that only 30 % depend directly on the number of ton-kilometres; we shall then obtain, in the case of electric traction, two values which determine our curve of costs: 15 500 000 fr. corresponding to zero activity and 22 594 000 fr. corresponding to 9.2 (that is to say 9.2 thousand million gross ton-kilometres), in the same way we find, for steam traction, 21 000 000 fr. and 28 983 000 fr.

It will be well to mention once more in the case of electric traction, the cost of current purchased, less the amount received for the sale of current produced in the generating stations of the railway that is $b_k = 1\,270\,000$ fr. We here assume a constant ratio of increase from zero, although this is not quite accurate. But the influence of this cost is so small that we may safely allow this small error to pass.

In the case of steam traction the cost of feed water and of the carriage of coal d_n , amount to 5 350 000 fr. They are directly dependent on the quantity of coal consumed. According to the report of the General Management, the consumption of fuel is directly proportional to the ton-kilometre and for 9 200 million gross ton-kilometres (5 600 million gross ton-miles), amounts to 500 000 metric tons (492 000 English tons).

In the case of electric traction, account must also be taken of the saving of 3 022 000 fr. effected on interest and redemption due to the Federal subsidy of 60 000 000 fr.

We are now in the position to trace (fig. 1) the curves of total expenditure E (electric traction) and D (steam traction). The great difference in the character of the two curves can be seen at once. With regard to steam traction, assuming the degree of activity of trade

inclination, shows the permanent nature of the costs of electric traction, whereas the line *D* rising more or less rapidly with the cost of coal, but in any case much more steeply than the line *E*, shows clearly the increasing value of the same costs for steam traction. For a small degree of activity, electric traction is costly and the cost may even amount to double that of steam traction, but as the traffic increases it becomes less and less heavy. This is clearly shown by the curves of cost of traction per gross ton-kilometre (per 0.6115 English ton-mile) (fig. 2). The cost per unit for steam traction also diminishes, but much less rapidly, as the traffic increases. In figure 3 we have shown, to a larger scale, the unit costs over the portion of the diagram which interests us more particularly between the degrees of activity 7 and 14. This diagram shows us in a striking manner, undoubtedly better than could be shown by any numerical table, that, in consequence of the adoption of electric traction, the financial efficiency of the Swiss Federal Railways has become, to a much greater extent than hitherto, dependent on the degree of activity or in other words, on the traffic.

The report of the General Management frequently lays stress on the property of electric traction mentioned in the preceding remarks, that is to say, the great diminution in the unit costs when the degree of activity rises, and it uses it as a weapon against those adverse to more rapid electrification, who, without having taken sufficient account of the character of the costs of electrification, can only see the large expenditure on installation, and do not notice the change in the character of the costs.

The objection might be raised, it is true, that it is not in the power of a railway management to increase the traffic at will in order to attain the degree of activity that is the most profitable to the undertaking, because, owing to external influences entirely outside

their control, the traffic is limited to a certain quantity. But this is only relatively true, because there are undoubtedly, large reserves of profitable traffic which could be attracted and brought on to the Swiss Federal Railway System by special low rates. It must not be forgotten, on the other hand, that automobile transport has become a serious competitor to all railways and is a competitor with which the electrified railway can, by reason of the large reduction in its unit costs as the degree of activity increases, carry on the struggle much better than a steam railway. The basis of the tariff policy, for improving the efficiency and enabling the rates to be reduced, should be supplied by a very thorough investigation into the composition and character of the costs, and this analysis should be made by taking the results of the theory, set forth above, as the starting point.

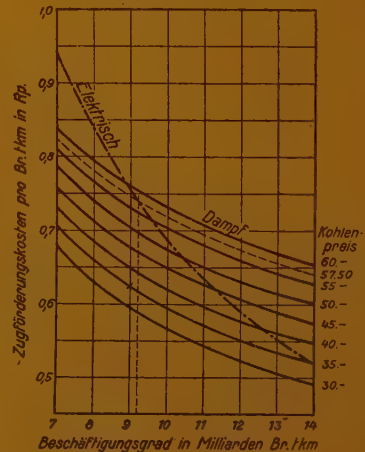


Fig. 3.

Translation of German term:

Kohlenpreis = Cost of coal in Swiss francs per metric ton.

Our graphical diagrams of costs (figs. 1, 2 and 3) do not only show for what cost of coal and for what degree of activity electric traction is more economical (equivalent cost); but they also

teach us what degree of activity *must be* reached to obtain good financial results with the probable receipts determined by the tariff.

Whereas the first of these two cases, which depends upon the equivalent cost of coal being ascertained, only comes into play when it is a question of deciding whether steam traction or electric traction is more economical, and has only a historical value at the present day; the second leads to the heart of the question which, as in all industrial enterprise must be of primary importance in the management of the Swiss Federal Railways; the improvement in the financial results by increasing the activity, or, as is rather the case here, the reduction of the freight rates without reduction of the efficiency. As the Swiss Federal Railways fortunately have no need to adopt any policy relating to dividends, what we understand in this case by efficiency is the net product necessary for the normal service of interest and redemption of the original capital, after deduction of all other expenses. We shall take up this question of railway expenditure later in conjunction with other questions, but in the first place we shall enlarge and develop our theoretical basis.

II — Limits of application of the curve of total costs.

The fact that the curve of total costs is only of limited application must not be overlooked: this is clearly shown by the example of the costs of electric traction given above.

It is not possible in this case to increase the traffic at will without increasing the number of locomotives.

Whereas a heavier consumption of current or a greater demand made on the staff shows itself immediately in the increasing costs and does not sensibly affect the form of the curve of total costs, increase in the number of locomotives

brings with it an increase in the fixed costs when the activity is greater than zero. A new curve of total costs results from this.

In our « Principles of the science of industrial costs » we have drawn attention to the great difference that exists between the cost of *production* and the cost of *preparation*. As we show in figure 4 the total costs of production may be divided into two parts; on the one hand the fixed costs of preparation (these costs are always fixed); on the other hand the fixed costs and increasing costs of production properly so called. Now *a single curve of total costs only holds true so long as the costs of preparation do not change*. On the other hand the cost of production may change in composition and character without affecting the validity of the curve of total costs.

Let us now suppose, for example, that on a railway worked by electric traction the locomotives available allow the traffic to be increased up to the degree of activity 8 of the scale. The costs are represented by the curve of total costs *a* and the corresponding curve of unit costs *a'*. If it is desired to increase the traffic beyond the degree of activity 8 and if it is not possible to obtain new locomotives, the only course open is to hire them. The original costs of preparation are not changed by this, because the hiring of these locomotives is shown only by an increase, in steps, of the fixed costs of production (or rather, in the case with which we are concerned, « of the working ») corresponding to the degree of activity 8. We thus learn of a new property of the costs; *the increase by steps of fixed costs*, which, however, only applies to the costs of production. Moreover it may be foreseen that the character of the increasing costs will also change, because, on the assumption that there is regular working carried on harmoniously, the generating stations will in turn no longer suffice and it will

be necessary to have recourse to high-priced current supplied by private companies. Finally a heavier wages cost must be expected, so that the variable costs rise more rapidly above the degree

costs of preparation increase and we obtain a new curve of total costs *b* which begins above the curve *a* but without any jump or change of inclination and having passed the critical degree of activity 8, falls again below, that is to say it becomes more profitable. From the corresponding curve *b'* of unit costs, it can be seen more clearly that though the reinforcement of the existing means of action of the railway, effected by a new investment, involves an increase of unit costs for a small degree of activity, it gives rise to a reduction of unit costs and is consequently economical when the activity increases. The same fact may be expressed by stating that the curve of total costs *a* corresponds to harmonious working up to the degree of activity 8, and the curve of total expenses *b* corresponds to a working that satisfies all the requirements and is economical even beyond the degree of activity 8.

Perhaps it is not unnecessary to draw attention to the fact that a rise in the degree of activity which has the effect of a progressive rise in the total costs only tends to diminish the costs when it is large. In our example, figure 4, the unit costs only drop after the degree of activity 11 below those corresponding to the degree of activity 8. In the graphical diagram of the total costs will be found the degree of activity that must be attained to bring about a further reduction in the unit costs, by drawing a straight line from the origin, < O > passing through the point S of the total costs at which the jump commences. The straight line OS then cuts the curve of total costs *a* again at the point S'; from this point the unit costs again become smaller.

This purely theoretical discussion has taken us somewhat outside the scope of our investigations. This is because, the more closely one examines the *dynamical* side of costs of production, the more imperative becomes the need for

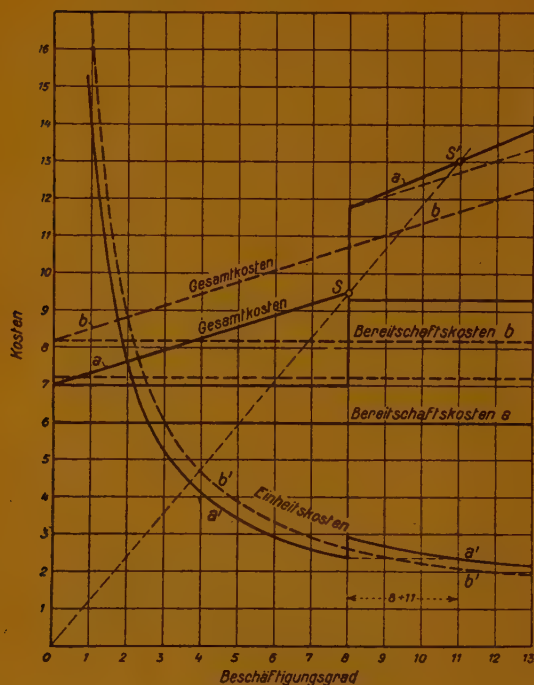


Fig. 4.

Translation of German terms: Beschäftigungsgrad = Degree of activity. — Kosten = Costs. — Gesamtkosten = Total costs. — Bereitschaftskosten = Costs of preparation. — Einheitskosten = Unit costs.

of activity 8. All this is shown graphically in figure 4; here will be seen the rise by steps of the total expenditure curve at the degree of activity 8 and its more rapid subsequent rise (curve of total costs *a*, curve of unit costs *a'*).

If, on the other hand, the railway increases its number of locomotives and enlarges its generating stations so as to meet the increase in traffic, in other words, if it has invested new capital, the

arriving at a clear appreciation of the theoretical basis which at present is far from being sufficiently well understood. But we find with pleasure that individual researches on this subject of the science of cost are increasing ⁽¹⁾ and with them the possibilities of investigating and completing the theory. Industry will acquire abundant profit from this scientific work; it has every reason to take part in and assist researches of this kind.

III. — Theoretical basis of rate-fixing.

The value of transport from one place to another forms the upper limit and the net cost forms the lower limit outside which the rates should not go. In this, or in an analogous manner, most of those who deal with railway rates have stated the bases of their schedule of rates. Hence they have established a principle which is directly applicable in spirit to the general problem of industrial prices and amounts to the statement that *in the long run it is not possible to sell a product below its net cost price*. The Act of the 30 August 1924 relating to the Imperial German Railway Company contains the statement under paragraph 2, on the same question : « The Company is required to carry on its working on commercial lines while safeguarding the interests of the German nation. »

One is obliged to recognize the fairness of this leading idea for the whole of a railway transport service that is not devoted to exclusively private uses, and at the same time admit the necessity for accurate calculation of the net cost. A mass of written matter shows us how far the problem of net cost occupies railway specialists, without its being at the present time considered as completely solved.

Our modest contribution, as we mentioned at the beginning of this note, has been made with no other object than that of verifying the results of the general science of costs in this particular case, and of pointing out certain properties of railway costs that appeared to us to be of peculiar interest. Perhaps we shall succeed in causing further investigations to be undertaken and gain fresh sympathy for this general doctrine that uses scientific methods.

Up to the present we have been obliged to confine ourselves to relatively small portions of the total costs, that is to the costs of traction. Now it is evident that if one wishes to go deeply into the problem of the railway costs the whole of the expenses must be considered.

The first question that arises then is this : what is the cost to us per ton-kilometre for goods and what is the cost per passenger-kilometre ? These are the two *coefficients of expenditure* and one of the principal tasks, in determining the railway costs, consists in compiling all the costs and distributing them between these two groups. Railway costs have a very important property : they consist of general charges only; in other words, amongst all the elements of the total expenditure costs, we do not find a single one of which one knows from the commencement to which group of expense it belongs. An error made in the distribution of general charges has greater effect in this case because these costs represent 100 % of the total costs, whereas in many industries costs such as those of materials of construction and wages of manufacture, which can be determined and distributed with certainty form the greater portion, so that the chances of error are rendered smaller.

It will be necessary therefore to study the composition and character of railway expenditure very carefully, noting

(1) See *Technik und Wirtschaft*, 3rd part., 1925, the article by the Certificated Engineer Hubert Drausfeld : *Aus der Dynamik der Preise* (Note on the Dynamics of costs).

beforehand that the total of various individual costs depends on factors that are hardly discernable in the ton-kilometre or the passenger-kilometre. When it is a question of building locomotives, for example, a certain relationship between the general charges and the total wages, by which the degree of activity is often expressed, may be taken as true. This factor is also found in the coefficient of expenditure under the form of direct wages so that the distribution of general charges on this basis is comparatively easy.

The formula that serves for calculating the unit cost, a formula which can well be applied to mechanical construction and to many other industries is in its simplest form the following :

Materials of construction + direct wages + General charges as a percentage on direct wages = Cost Price.

For a railway service where the direct wages and the cost directly determinable for material are not available, the formula for calculation is still more simple:

That part of the group of rates which comes into the total or general expenditure divided by the unit rates = the cost price.

The total expenditures and the number of unit rates are a function of the degree of activity; their determination in advance rests on estimates based on statistical data and theoretical considerations relating to the costs and necessarily includes an element of uncertainty. The difficulty of the problem of the cost price on a railway depends above all on a good understanding of the interdependence between the total costs and the degree of activity.

Before going further, it will be well to take a brief survey of the composition of the *total costs of working a railway*.

Apart from the costs of working, properly so called, which in accordance with the requirements of the « Federal law relating to the account-keeping of the Swiss Railways » are divided as follows :

1. — General management;
2. — Maintenance and inspection of the track;
3. — Station and train services;
4. — Traction and running-shed repair-shop services;
5. — Miscellaneous expenditure.

the total costs necessarily comprise *charges on the capital* as well which we extract from the profit and loss account and may be expressed as follows :

6. — Interest on loans and floating debts, subject to deduction of the total capital not in use and to deduction of receipts from auxiliary services not directly connected with the working of the railway;
7. — Repurchase, redemption, and the balance left from the renewal fund after meeting the liabilities.

In table I below we have shown as an example these details of costs taken from the report of the R  tian Railways for the years 1921 to 1923. It is to be noted that no interest on the share-capital appears in these various headings.

The heading « Repurchase and redemption payments » could not be reproduced in its original form in the profit and loss account because the effects of the change from steam traction to electric traction and of the slump still made themselves clearly apparent by figures that changed by sudden jumps and did not depend on actual reductions in value. It would moreover take too long to give our theories in full, though they approach very closely to the actual conditions.

TABLE I.

Total costs of the Rhaetian Railways for the years 1921 to 1923.

ALLOCATION.	1921		1922		1923	
	Swiss Francs.	%	Swiss Francs.	%	Swiss Francs.	%
General Management.	280 000	2.5	282 823	2.4	278 337	2.4
Maintenance and inspection. . . .	1 551 817	13.6	1 513 513	12.6	1 321 908	11.4
Station and train services	1 728 947	15.2	1 765 618	14.8	1 657 153	14.2
Traction service and running-shed repair-shops	3 361 646	29.6	3 140 934	26.4	2 880 558	24.8
Various expenditure	627 145	5.5	706 444	5.9	648 929	5.6
Interest on loans	3 006 761	26.5	3 667 199	30.7	3 930 761	33.7
Repurchase and redemption pay- ments	811 033	7.1	860 669	7.2	920 000	7.9
Total expenditure	11 367 571	100.0	11 937 200	100.0	11 637 646	100.0
Ratio to total expenditure	1.00	...	1.05	..	1.02	...
Ton-kilometres (English ton-miles) carried.	132 672 000 (81 138 000)	..	158 617 399 (97 005 369)	...	178 363 483 (109 081 449)	...
Train-kilometre. (train-miles) run.	1 107 488 (688 174)	...	1 309 562 (813 738)	...	1 446 745 (898 981)	...
Traffic receipts	10 124 894	...	9 470 428	...	10 390 544	...

This table and the diagram given in figure 5 show in the first place that the total costs are remarkably constant for the three years in question whereas the traffic in ton-kilometres and in train-kilometres, has undergone greater variations. It will be seen, moreover, that the composition of the total expenditure has also not varied greatly. A certain change over however, appears; the costs of traction and running sheds diminish and the amount paid in interest on capital increases year by year. These differences show that as a consequence of the progress of electrification there is a reduction in the costs of working and on the other hand there are

heavier capital charges due to the electric installations. If, by a large investment, economies are effected in working and, on the other hand, the increase of interest and renewal of capital charges are neglected, an inaccurate result is obtained that is much too favourable.

It would therefore be an error to proceed with theoretical researches into the costs by taking the cost of working as the sole basis; similarly, the customary comparison of the coefficients of working has not much value, but, on the contrary, may lead to false conclusions. Thus, for example, using the figures in

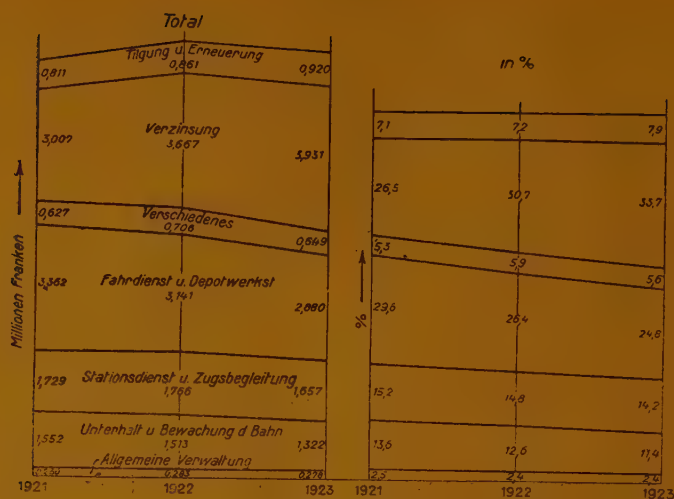


Fig. 5. — Graphical diagram of the costs given in Table I.

Translation of German terms: Allgemeine Verwaltung = General management. — Fahrdienst u. Depotwerkst. = Traction service and workshops at running-sheds. — Stationsdienst u. Zugsbegleitung = Station and train services. — Tilgung u. Erneuerung = Repurchase and redemption. — Unterhalt u. Bewachung d. Bahn = Maintenance and inspection of the track. — Verzinsung = Interest. — Verschiedenes = Various. — Millionen Franken = Millions of Swiss francs. —

table I, we find the following ratio between the total costs and the receipts

from working, with coefficients of working as follows:

	1921	1922	1923
Total costs, per cent of receipts of working	112.27	126.05	112.00
Cost of working, per cent of receipts from working = coefficient of working	74.56	78.24	65.32

The report of the Swiss Federal Railways for the year 1924 has, moreover, indirectly shown this inherent defect in the coefficient of working. In 1924, the coefficient of working of this railway system closely approached that of 1913. It was 67.25 % as against 66.94 % in 1913. But, on the other hand, the amount paid in interest was increased by 47 700 000 fr. so that the real ratio between expenditure and revenue in 1924 is still far from having reached the favourable level of 1913.

The striking uniformity of the total costs of the Rhaetian Railway in three consecutive years cannot be quoted as a

definite argument in favour of the obviously very small total costs as compared with the degree of activity. It might happen that other factors, such for example as large changes in wages or cost of materials had caused this remarkable compensation and made the result unreliable. It would therefore be necessary, in order to prove it, to refer all the expenditure of the three years under consideration to a common basis. We may, however, proceed otherwise so as to take account of the character of these total costs. A first glance at the balance-sheet, which gives in great detail the figures in the report of the

Rhætian Railway Company enables us to come to the following general conclusions :

I. — The expenses of *General Management* are fixed, that is to say they are independent of the degree of activity.

II. — The costs of *maintenance and inspection of the track* are also fixed for the greater part, but may be increased slightly when the traffic becomes more heavy.

III. — The costs for the *station service* are nearly fixed, and those relating to the *train service* vary to some extent with the traffic.

IV. — The details of the costs that increase most with the traffic are found in the *traction service*, and, to a less degree, in the *running-shed workshops*.

V, VI, VII. — The headings *Various expenditure, Interest, and Redemption* only contain fixed details for the greater part; it should, however, be noted that these figures are not taken direct from the accounts, but that some of those we have obtained are estimated.

To make the preceding easier to understand we shall try to supplement these theories by numerical examples, taking the year 1922 as a basis, for which we have estimated the character of the costs as shown in table II.

Although this division into fixed costs and increasing costs is not based on a detailed analysis of costs, an analysis that could only be made by an official of the railway, but by simple estimating, the reasoning is nevertheless sufficiently close to enable us to state that, in the working of the Rhætian Railways, the fixed costs represent at least 90 % of the total costs; and this helps to support our hypothesis that, *in the working of a railway the total costs are in great part independent of the degree of activity*, a conclusion that is of great importance in tariff policy.

We shall now show this result in the form of a graphical diagram and at the same time give the unit costs corresponding to different degrees of activity (fig. 6). As a measure of activity we have for the moment chosen, the « ton-kilometre charged » a unit that expresses the efficiency with a sufficient degree of exactitude. The details of total costs that depend on the degree of activity are shown proportionally; this is also a hypothesis which it will be necessary to make clearer by a detailed analysis of the costs.

The hyperbolic form of the curve of unit costs shows clearly to what a great extent this cost depends on the degree of activity, and shows the possibility of improving the latter by a reduction of tariffs and thus covering the total expenses rather than by means of high tariffs and small traffic. In support of this assumption we will take an example : The rates correspond to activity 9 and consequently if this degree is reached, the rates will suffice to cover the total costs exactly. But in consequence of excessively high rates, the traffic slackens and we only attain an activity of 8. The loss is then in round numbers 1 070 000 fr. By reducing the rates by about 10 %, one obtains an appreciable improvement in the degree of activity; when activity 9 is reached the loss is still the same as it was before for degree 8. But as, owing to the cheaper transport, the traffic continues to increase, activity 10 is reached so that the two objects of the rates : recovery of the cost price and protection of the national interests are secured. The form of the curve shows moreover how a deficit is to be feared when there is a poor degree of activity.

If now we consider that a definite number of ton-kilometres for which payment has been received may consist of an infinite number of variations in passenger-kilometres, in luggage-kilo-

TABLE II.

Total costs of the Rhaetian railways for the year 1922.

ALLOCATION.	Total.	Expenditure independent of degree of activity.	Expenditure dependent on degree of activity.
	Swiss francs.	Swiss francs.	Swiss francs.
I. General management	282 823	282 823	...
II. Maintenance and inspection of the track :			
A. <i>Salaries and wages, including supervision</i>	771 267	771 267	...
B. <i>Incidental expenditure</i>	55 965	55 965	...
C. <i>Maintenance :</i>			
1. Below the road-bed	211 780	211 780	...
2. Above the road-bed	223 217	200 000	23 217
3. Bridges, tunnels and mechanical installations	66 472	66 472	...
4. Signals and telegraphs	49 932	49 932	...
5. Removal of snow and ice	134 880	134 880	...
III. Station and train services :			
A. <i>Salaries and wages :</i>			
1. Running staff	62 525	50 000	12 525
2. Station staff	1 223 388	1 200 000	23 388
3. Train staff	369 952	300 000	69 952
B. <i>Incidental expenditure</i>	109 753	100 000	9 753
IV. Traction service and workshops at running-sheds :			
A. <i>Salaries and wages :</i>			
1. Supervisory traction staff	60 838	60 838	...
2. Train staff	847 027	800 000	47 027
3. Equipment and cleaning staffs	203 102	160 000	43 102
B. <i>Incidental expenditure</i>	75 209	75 209	...
C. <i>Stores and energy consumed :</i>			
1. Fuel	96 116	60 000	36 116
2. Electric energy	843 159	500 000	343 159
3. Oil and light	41 709	30 000	11 709
D. <i>Maintenance and renewals of mechanical and electrical installations</i>	59 060	59 060	...
E. <i>Maintenance and renewals of rolling stock :</i>			
1. Steam locomotives	57 505	40 000	17 505
2. Electric locomotives	388 939	300 000	88 939
3. Passenger carriages	238 305	180 000	58 305
4. Luggage vans and goods wagons	225 542	180 000	45 542
5. Vehicles for internal service	4 423	4 423	...
V. Various expenditure :			
A. <i>Rents of farms and buildings</i>	14 084	14 084	...
B. <i>Other expenditure</i>	692 360	692 360	...
Total working expenditure	7 409 332	6 579 093	830 239
Ratio %	100	89	11
VI and VII. Interest and redemption :	4 527 868	4 527 868	...
Total expenditure	11 937 200	11 106 961	830 239
Ratio %	100	93	7

metres and in ton-kilometres of goods, and if we consider, moreover, that the magnitude of these details of costs that

unknown quantities: this variable is the *time-table*.

Determined in advance for each year the time-table gives, at any rate in times of normal activity, the kilometres run by locomotives, by trains, and other transport, as well as the number of axle-kilometres obtained from the usual make-up of the trains. The corresponding dead load in ton-kilometres is determined thus once for all, whereas the useful load may rise from 0 to a maximum possible value a . The increasing traffic might be ensured beyond a without increasing the number of the trains and their mileage by merely modifying the make-up of the trains; that is to say, by increasing the number of axles per train and hence the number of axle-kilometres; let b , in ton-kilometres be the limit. A new increase in the traffic from b to c ton-kilometres then requires a greater number of trains.

We have tried to show these conditions graphically in figure 7; and we find the following: The train-kilometres remain the same as far as b and continue afterwards in steps. The axle-kilometres remain the same from 0 to a and continue afterwards by steps; the dead load (in ton-kilometres) is constant up to a and then increases by successive jumps with the axle-kilometres. The total load or gross load, which is the sum of the dead load and the useful load, serves to measure the degrees of activity a , b and c .

It should be noted that the ton-kilometres of useful weight that serve as a measure of the activity are not the same as, but are less than the useful ton-kilometres theoretically possible that would be obtained by multiplying the load per axle by the axle-kilometres. In fact all our investigation has had as its object the predetermination of the cost price with a view to fixing the tariff rates, and should not be based upon the heaviest possible tonnage carried, but on the

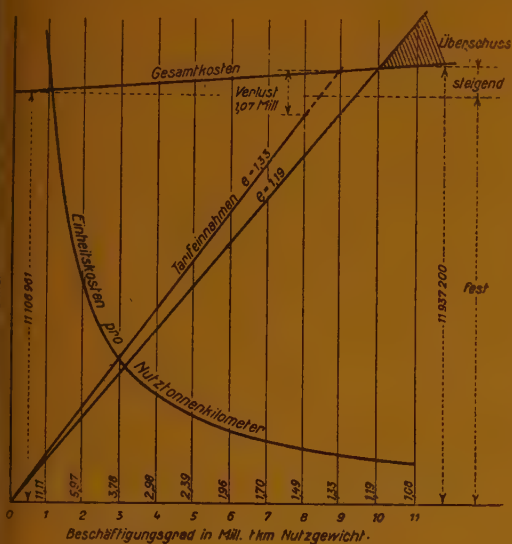


Fig. 6. — Graphical diagram of the costs of the Rhätian Railway in 1922, as given in Table II.

Translation of German terms: Beschäftigungsgrad in Mill. t-km. Nutzgewicht = Degree of activity in millions of useful ton-kilometres. — Einheitskosten pro Nutztonnenkilometer = Unit costs per useful ton-kilometre. — Fest = Fixed. — Kosten in Franken = Costs in Swiss francs. — Steigend = Increasing. — Tarifeinnahmen = Receipts. — Ueberschuss = Surplus. — Gesamtkosten = Total costs. — Verlust = Deficit.

are a function of the degree of activity depends on several factors that differ entirely amongst themselves; train-kilometres, locomotive-kilometres, axle-kilometres, gross ton-kilometres, etc., etc., it will be seen how great is the difficulty of finding a common standard that will serve to measure the traffic and at the same time determine the amount of the total costs. We here find ourselves met by the essential problem of the theory of railway costs, the solution of which is perhaps rendered easier on finding that a single variable, and one that is quite obvious, enables us to eliminate the greater number of these

tonnage that may reasonably be expected. Consequently one cannot expect complete utilization of the carrying

capacity of the trains for the whole of the train-kilometres provided according to the time-table.

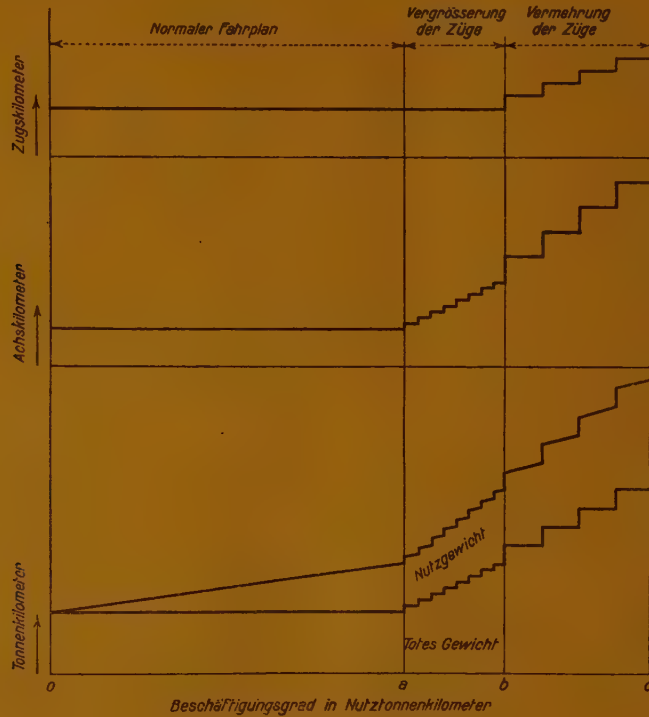


Fig. 7.

Translation of German terms: Beschäftigungsgrad in Nutztonnenkilometer = Degree of activity in millions of useful ton-kilometres. — Achskilometer = Axle-kilometres. — Zugkilometer = Train-kilometres. — Normaler Fahrplan = Normal time-table. — Vergrößerung der Züge = Increased length of trains. — Vermehrung der Züge = Increased number of trains. — Nutzgewicht = Useful load. — Totes Gewicht = Dead load.

The graphical diagrams showing train-kilometres, axle-kilometres and ton-kilometres show that the variable costs that we have still supposed to be proportional in figure 6 will, according to expectation have a progressive character. Within the limits of the normal time-table from 0 to *a*, the costs will hardly increase, that is to say they will not increase except under the influence of an increasing useful load; it is in the sec-

tion *a-b* which, moreover, will be much smaller in proportion to 0-*a* than we have drawn in our diagram, that the progression commences which continues beyond *b*. Generally speaking the influence of the elements of variable costs on the total cost is not very large because they only form a small percentage. On the electric railways that have their own generating stations the expenditure on current also has an almost fixed

character, so that these undertakings are extremely sensitive to fluctuations in the traffic.

The absolutely essential division of the total expenses into costs of passenger transport on the one hand, and goods on the other, cannot be determined by the accurate analysis of the composition of the cost alone. For a great number of details of expenditure one may, it is true, determine definitely into which category they must be placed; others, on the other hand, such for example as the costs of general management and miscellaneous expenses must be divided arbitrarily, whereas the part for which the construction of the railway comes into the establishment costs, as well as the cost of maintenance and inspection of the track, may be very fairly separated and divided in the ratio of goods axle-kilometres to passenger axle-kilometres. Here other reasons, perhaps of an economical order make the balance turn in favour of one group or the other. It is obvious that we must not conclude from this statement that the method is defective, because the theory of costs should never be regarded except as an accessory to economical considerations.

Once the division of the costs between the passenger traffic and the goods traffic has been made, it is evidently no longer possible to adopt the number of useful ton-kilometres for the passenger traffic as the measure of the degree of activity; it would be necessary to replace this by the passenger-kilometres to which the useful weight necessary for the determination of the total cost will be proportional.

The total of the probable receipts from rates will be obtained for a degree of activity determined by estimating,

with the help of statistical data, concerning the proportions of 1st, 2nd and 3rd class passengers and the lengths of their journeys, or in similar manner that of the different classes of goods. Here theory must give way to statistics.

The rates are not necessarily fixed for the period of the time-table but for as long a time as possible. During the length of time they are in force radical changes may intervene, not only in the time-tables, but also in the details that make up the costs. Notwithstanding the impossibility of modifying the principal articles relating to the rates the total expenses should be calculated afresh for each new time-table by analytical methods based on the results of statistics and we should then proceed to the valuation of probable receipts from goods traffic in order to have available the necessary information for avoiding, as far as possible, by exceptional rates the losses that might be feared; in this way we shall be placed in a better position for satisfying the general economic requirements without interfering with the economical conduct of the undertaking.

It may consequently be said for railways, as for all other industries, that : *The problem of costs is dynamic in character and not statistical because the unit costs of production are a function of the degree of activity.* It is therefore necessary to know the character of the costs in order to be able to guard, by a broadminded policy of prices, against the influence of variations in the traffic and to retain for the undertaking the degree of activity which will guarantee economic running at the rates that can be obtained.

One hundred years of railways,

By NICOLAS PAVIA,

DOCTOR OF ENGINEERING, ITALIAN STATE RAILWAYS.

Figs. 1 to 6, pp. 553 to 565.

(*Ingegneria*)

On the 3 July last, on the occasion of the 10th session of the International Congress at London, England celebrated the first centenary of the birth of railways.

It was in fact on the 27 September 1825 that the opening of the Stockton to Wilton Park (Darlington) Railway took place, an event of which the English had already celebrated the fiftieth anniversary in 1875 by an exhibition, which was held near the North Road engine works.

To be precise, it should be pointed out that rudimentary railways and engines had already been in operation for some time for the service of collieries and mines. The Stockton and Darlington line, however, was the first to be put down for the use of the general public, and its length was considerable for those days (about 10 miles), and it was constructed with double headed rails of rolled iron ⁽¹⁾, 15 feet long, weighing

26 lb. per lineal yard (at £12.10 sh. per ton), and partly fixed on oak supports cut from old wood taken from ships.

The trains were hauled by the celebrated engine *Locomotion No. 1* (fig. 1), and the cost of the line amounted to the large sum, for that period, of £250 000.

There are good grounds, therefore, for approximately dating from this time the great transformation which took place in the method of dealing with transport, and which represents with its rigidly fixed guiding track the road of modern civilisation. Other technical critics, however, consider that the more exact date of the birth of railways is 8 October 1829, described by Clark in his work *Railway Machinery* published in 1854, as the revolutionary date. This is the historical and sensational date of the Rainhill trials, where for over a distance of 30 miles of the Liverpool to Manchester line, George and Robert Stephenson

(¹) Even today the statement is often heard that the line was made up of old rails described as "of section of equal resistance" (commonly called fish-bellied), and 3 feet long. Stephenson, however, only used this type for a short time while he was trying to convince his directors of the advantages that were to be derived from wrought iron, which the metallurgist Berkinshaw had succeeded in rolling for the first time in 1820. These were more costly (£12.10 sh. per ton against £6.15 sh. for cast iron), but their

general utility for the purpose was much greater.

At last Stephenson overcame the hesitations of his board of directors, and had the Stockton to Darlington line, as well as later the Liverpool to Manchester line, constructed with this kind of rail.

Steel rails were not used until 1857, after Bessemer had succeeded in producing this metal on a sufficiently large scale at reasonable price. (FLAMACHE, conference of November, 1912, and TAYLOR's memorandum of 1923).

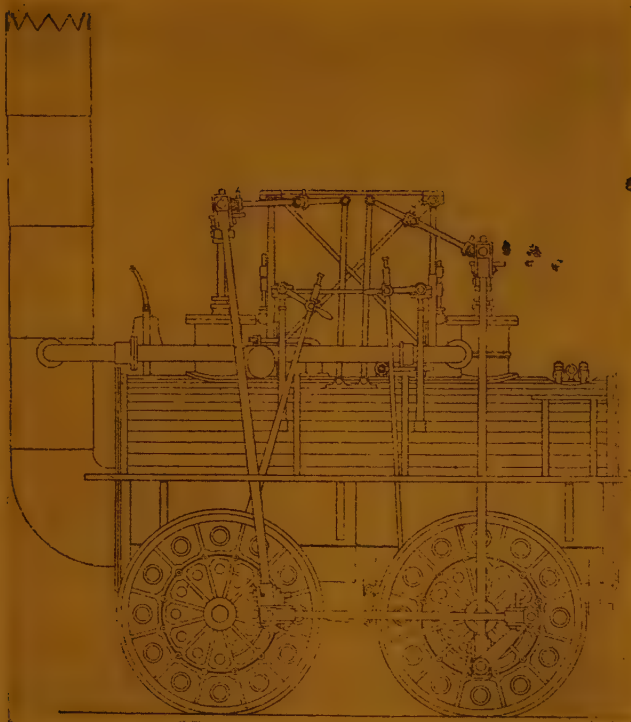


Fig. 1.



Fig. 2.

proved their mastery with the nineteenth locomotive built by them in their primitive works at Forth Street, Newcastle.

This engine, called the *Rocket* (fig. 2), is now preserved in the South Kensington Museum at Brompton, and its ingenious mechanical construction contained the fundamental principles which made it successful, and which have not been departed from up to the present time (tubular boiler and steam exhaust up the chimney). The work it was able to do, its speed and the long distance it was able to travel, encouraged capitalists who up to then had been hesitating, and thus began the era of a more intense life, and a fever of production and consumption which tended to reduce to a minimum losses in energy, with a better use of time, in comparison with the rudimentary methods employed up till then, and which necessitated an unlimited amount of labour whilst time was considered of little importance.

Up till then, propulsion was only accomplished by means of animal haulage or by wind power, so that the creation and improvement of steam engines was a prodigious step forward, even as are today the conquests and exploits in aeronautics.

The intellectual activity of the two Stephenson, fully described in various biographies, amongst which we will mention those of Samuel Smiles (*Life of G. Stephenson*, London, 1859), and of Jefferson and Pole (*Life of Robert Stephenson*, London, 1864), may be summed up as a continual effort, by means of reasoned science, and a constant desire to build up from theory to practice.

Their numerous predecessors, however, should not be forgotten, who helped by their investigations to sharpen these spirits, so ardent to learn and so willing to be instructed.

We may mention, for example, James Watt of Greenock (1736-1819), celebrated for his study of steam and its expan-

sive properties, and his beam engine with parallel motion.

Trevithick, with his practical demonstration of traction by means of steam (1804); Papin (1705), who had the intuition of the utility of superheat; Blackett, who in 1811 demonstrated that two smooth rails were sufficient to give the necessary adhesion, provided the load was properly distributed.

Many others might be mentioned, and particularly Timothy Hackworth, who was at first engineer at the Stephenson's works at Newcastle, and later (1827) locomotive superintendent of the Stockton and Darlington Railway, and who gave such an impetus to the evolution of the important and delicate mechanism for the distribution of steam in locomotives.

In a remarkable series of articles published in the *Engineer* of 18 June and 2 and 9 July 1920 (1), James Dunlop gives an original contribution to the question to this particular evolution starting from 1811, when by a curious coincidence the first rudimentary locomotive (for use at the Middleton mines), and the first steamship (the *Comet*), were fitted with valve gears, though it is true differently arranged, the one by Murray and the other by Blenkinsop, but whose action depended on revolving devices fixed to the essential working parts of the engines.

The work by Dunlop on the subject is a most valuable document dealing with historical and pioneer investigation.

Special reference is made to *Locomotion No. 1*, already referred to, the feature of which, from a mechanical point of view, was the adoption of parallel motion which took the place of the fixed guide bars then in use, and a special reversing gear with loose eccentrics.

(1) *Bulletin of the International Railway Congress Association*, March, 1921.

This locomotive, which made its first journey 27 September 1825, under the supervision of George Stephenson and his elder brother James, was kept at work up to 1841, when it was transformed into a stationary engine, and ran in this form up to 1857. It was then shown working at the 50th anniversary mentioned above (1875), and finally figured last year at the British Empire Exhibition at Wembley as a tiny ancestor of the colossal engine the *Flying Scotsman*, exhibited by the London & North Eastern Railway in order to show the immense stride that had taken place since this light engine, weighing only 6 1/2 tons (pressure 25 to 50 lb. per square inch), up to this powerful *Pacific* engine of the present time, which weighs 23 times as much. Since working for the last time, a symbolic resting place has been allotted to it on a pedestal at Darlington Station.

It should be pointed out that a serious mistake has been made in replacing the valve gear, which could not possibly work as now fixed.

It is therefore difficult to form a proper idea of the arrangement of its motion except after a close examination, from which it may be seen that for the first time use was made of a single eccentric working two slide valves distributing steam to two pistons working cranks fixed at right angles; also for the first time lap and lead were introduced (with an angular advance of 19° for both running directions).

The first few miles of line which comprised the Stockton to Darlington Railway were speedily followed by the construction of lines from Liverpool to Manchester (1830), London to Birmingham (1838), and Chester to Holyhead (1848). Up to 1830, about 153 miles had been laid down in Europe, and 55 in America, which began with the Maunch-Chunk Railway in 1827. The total mileage of the railways of the world in 1840

had risen to 4 812, and at the end of 1924 to 812 500, with a colossal investment of capital, if we consider that the last estimate given by the *Journal of the Statistical Society of Paris* at the end of 1885 was £5 204 680 662 for the total mileage of 292 337 which existed at that time.

The daily traffic (still in 1885) amounted to 6 millions of passengers, and 3 600 000 tons of goods.

The first trains run were neither safe nor comfortable. The third class carriages were completely open, and without seats; the second class were unprovided with windows, the doors were very narrow — only 17 1/2 inches wide — and the seats 15 inches wide, which put the poor passengers in a very awkward position, having to cheer one another up during a journey. In addition should be mentioned the determined opposition railways met with from those who were bitterly opposed to all innovations, and these persons were numerous and not without influence. Thus, though there were a few men like Perdonnet, who proclaimed from his chair in 1832 that the beneficent revolution which had given « new wings to Mercury » was unavoidable, and would influence the world as much as printing, most people were very hostile and opposed to the Railway. Amongst the latter may be mentioned the renowned historian and politician, afterwards Prime Minister, Thiers, who in 1834, after having visited the Liverpool line, said its only use was to amuse loungers.

Nevertheless what one man by himself did not dare to do, ten others leaped into the breach under the miraculous influence of example, and many people began to use the new means of travelling.

Learned men and doctors, however, continued to make it a point of professional honour to enumerate and describe all the terrible consequences

which must inevitably result from this foolhardy invention.

François Arago, who later on (1837) publicly renounced his former prejudices by giving a splendid tribute to his fellow-countryman Marc Séguin, French rival to the Englishman H. Booth in the invention of the tubular boiler, did not hesitate at first to raise the spectre of pleurisy, which he said travellers could not escape in passing through tunnels, even if they were lucky enough to be saved from explosions of the locomotives themselves.

Other learned persons foresaw the mortal effects that would happen to the respiratory organs through the rapid passage from one climate to another, or the starting of nervous complaints due to mechanical vibrations, and cerebral affections due to the continual apprehension of coming danger, and a permanent ulterior state of anxious trepidation, and the gynecologists predicted certain risks as regards abortion.

The higher classes of society particularly showed their scepticism concerning railways. It is sufficient to point out that in England, the Duke of Wellington only used the new method of transport in 1842, and Queen Victoria in 1843, which places the example shown in Italy by Ferdinand II in a particularly bright light, for he did not hesitate quite early (2 October 1839), with all the splendour of his court, to ride in the inaugural train, the speed of which was 28 miles per hour, on the Naples-Gratello-Portici line, which was worked by two single wheeled locomotives constructed by Longridge Stobart & Co., of Newcastle. This event caused the highest enthusiasm amongst the Neapolitan population.

Everywhere else popular imagination gave the new system of locomotion the warmest welcome. Simple refrains circulated amongst the masses praising the railways and making fun of the stage

coaches, and went so far as to stage a revue « made up of mechanism with stanzas in steam ». This success, favoured at the same time by the rapid improvement of the rolling stock, increased to such an extent that about 1842 the measures taken at first to lock the passengers in their carriages for fear of their being suddenly frightened by the sound of a whistle or the passing through a tunnel, which might induce them to jump on to the track, were suspended.

So much so, in fact, that finally the retrograde mentality of Alphonse Karr, who said how annoyed he was with railway cuttings « through which one goes but does not travel », was superseded by the poetic and suggestive aspiration of Jules Janin, which said « I love the railway because it brings to us the forest, songs, joyous walks, fresh air, heaven and the spring ». This is still to day an aspiration in spite of the exigencies of the present somewhat high mode of living, which embraces the sea, the mountains, sports exhilarating and exciting excursions, an increased æsthetic culture, so that it cannot be truthfully said that the modernism of these hundred years of fire and flame is in any way responsible for the scattering of all that was intellectual and sentimental, which was denounced for instance by Guglielmo Ferrero in his recent insidious editorial article in the *Illustration* (18th April), an effusion in which he endeavoured to show that it was the ransom imposed on humanity for the power with which the railways and engines had endowed them.

In this manner, therefore, railways spread everywhere, climbing the highest altitudes, such as the Lima-Oroya pass (15 647 feet), passing through long and massive mountain ranges (Simplon Tunnel, about 21 700 yards), the success of this last effort being due to the new method of tunnelling, the first decisive

step being successfully accomplished by the Italians Sommeiller, Grandis and Grattoni, by piercing the Fréjus tunnel (14 130 yards long at an altitude of 4 248 feet) in October 1857, when all had to be thought out and organised even against the prejudices of individuals who believed themselves learned and enlightened.

After having benefited all the civilised nations, railways stretched forward into the Congo, India, the Soudan, from Pirea to Larissa, from Dakar to St. Louis, with the immense works of the Transcaspian and the Transsiberian, peacefully penetrating into new countries waiting to be colonised and civilised according to modern ideas.

When the Turkomans first saw the « Iron Horse », they cried out at once that it was no longer possible to fight the Russians, because the latter had sent circles of iron to subjugate their country. It is certain that railways made a varied and huge impression on the minds of natives all over the world, and they generally received the first locomotive sent to them with enthusiastic shouts of joy.

Formerly the usual method of transport was by means of the « Ship of the Desert », namely, the camel the efficiency of which was very low (about 2 miles per hour) and necessitated night stages, and defence and protection against raids. Everybody knows the terrible difficulties met with in the expeditions to Madagascar, Abyssinia, the Congo, in the Caucasus, and by Livingstone and Stanley when it was necessary to cross sandy countries without water, and with obstacles continually cropping up in the midst of savage tribes. It is only necessary to read the *Voyage du Derviche tourneur*, by Vambéry, to learn in the clearest way of the sufferings and difficulties experienced on these expeditions. Today railways are established on a sure footing in these districts,

so rich as regards cultivation and prosperous in commerce and industry. The old Roman road now uses steam to complete the terrestrial harmony between the nature of the soil and the physico-economic destinies of society in order to form new hives of riches and new centres of civilisation. There is no doubt that in time the audacious scheme of crossing the Sahara by a railway will eventually be accomplished, the action of the slow marching caravans having already formed a track dotted with oases which always keep green, and the neighbourhood of which can be transformed — at least in Northern Africa — into fertile territories. Ancient legends and modern discoveries reveal that the actual country of thirst and desolation has not always been so naked and miserable, and consequently may yet be called to a great future, as firmly believed by Blanc, for instance, in his work *Le dessèchement du Sahara et l'avenir des oasis*.

Railways have also changed the physiognomy of modern warfare, in radically modifying the conditions relating to the preparations necessary in the struggles between nations. Armies which face one another today are composed of hundreds of thousands of men, who have to be gathered together, transported, supplied with food and ammunition, and taken away rapidly when wounded; so that the number of problems which have to be solved for the successful conclusion of the operations has become of considerable importance, as proved in the last great war. By their very nature railways do not allow of any retarding influence, however slight. They therefore form the instrument of precision best adapted for success in war, provided that care has been taken in good time — as is now done in all states since 1870 — to intimately combine the military and technical elements.

In the course of years railways have

been considerably improved. The first trains which dragged slowly along from station to station with much noise and clatter of metal, have become much more stable, powerful and agile, and run with a lively and majestic demeanour.

The æsthetic qualifications of speed have also become an attribute of this monster of metal and flame, and these were strikingly brought into prominence by the expresses which were sent in various directions in England on 24 November 1847, to distribute newspapers after an important debate in Parliament when the political situation was very acute. Of these expresses (see *The Engineer*, 17 December 1897) should be mentioned the special train from London (Euston Station) to Beattock, which accomplished the journey of 341 miles in 552 minutes, an average speed of 42 1/2 miles per hour (including losses of time during the journey, consisting of four changes of engines, stopping for water, stops at junctions, etc.). This is quite a remarkable speed for a time when the block system had not been introduced, and the rails were attached to stone blocks, and therefore not very solidly fixed. Fishplates also had only just come into use, and very few had then been fixed (the patent had only been taken out six months previously).

We should point out also that in 1855 the locomotive *Wellington Bank*, with wheels 9 feet in diameter, attained a speed of 82 miles per hour, and that in 1890, engine No. 604 of the French Eastern Railway (old *Crampton* with single wheels) attained a speed of 90 miles per hour over the short distance between Montereau and Sens. In 1897 a speed of 90 1/2 miles was reached and maintained over a length of three quarters of a mile by a single wheeled « Midland » engine, the drivers being 7 ft. 9 in. in diameter. Finally, 124 1/2 miles per hour were attained on 6 October and

later 131 miles for six seconds on the morning of 25 November, 1903, on the Marienfeld-Zossen line. The latter was observed by a board of enquiry with the object of giving a new and profitable impulse to the future developments of transport; whilst later (in 1904) in a supreme spirit of rivalry, the steam locomotive was enabled to pull on the same line and afterwards on the Göttingen to Kreiensen line, the heavy « D » class of trains (inter-circulation service) at a speed of 85 miles per hour. (See *Die Woche*, 9 April 1904.)

These trials, and experience gained, led to general increases in speed, to such an extent that before 1914 the limit of 76 miles an hour was exceeded on long stretches of line both in France and England. On the American side also, the super-express of the Philadelphia & centres, where the desire, on account of 81 miles an hour at various points of the line from New York to Chicago.

Since the great war, however, prudence seems to have taken the place of boldness, and today speeds have been somewhat reduced, and the old custom of giving bonuses to drivers for the fastest runs has been substituted by that of making them responsible for not exceeding the limit allowed, even for short distances.

In spite of this there is a certain amount of bold initiative appearing, especially in Italy, to obtain high speeds on first class lines between populous centres, where the desire, on account of business rushes, is for the towns to be as closely connected as possible so far as time is concerned.

Such future trains, though, will be neither larger nor heavier than those of to day. As regards this, that shrewd writer, Mario Morasso, was a very far-seeing prophet. In the *Nuova Arma*, in 1905, he predicted and described, so to say, the simplification and composition

of the future trains, which he said would be very fast, unencumbered with various classes, and following one another at short intervals with that impetuous velocity which is the « glorious victory over dull weight », as pictured by d'Annunzio.

A new state, however, of technical and moral conditions is arising and making itself felt; the conquests of aero-dynamics transferred and substituted as experimental theory to the old laws relating to air resistance (Smeaton, Davis, Aspinall, etc.), and as constructive practice bringing about the relinquishing of actual conditions with appropriate sections and surfaces, will allow the new kind of train to skim the earth with less difficulty, and penetrate with less resistance space at a more prodigious speed, rushing ahead unremittingly in the direction of progress, from which, after all, happiness is born.

While waiting for the accomplishment of this attractive programme, the steam locomotive continues to fulfil its beneficent mission, and is continually developing, especially in power, up to the weight limit with which it is handicapped, namely, 18 tons per axle in Europe and 22 in America.

From the point of view of simplicity, because it works as a *self-contained* unit, it evidently possesses serious advantages over any other combination made up of complex elements for propulsion, so that its moving arrangement of pistons has resisted up to now, for this purpose, all other forms of motive power.

For stationary purposes, it is true, the steam turbine and dynamo have to a great extent supplanted reciprocating engines, and the same has happened with ships, in which since the first historical application made by Parsons in the torpedo boat *Turbinia* (1898), the benefits from its adoption have been found to be enormous and justifiable. On the other hand, the struggle taking

place to apply the principle of the turbine to the locomotive, attempted by Behrisch-Orange, Belluzzo, Reid-Ramsay, North British Locomotive Works, Ljungström and Krupp, does not allow us yet to form an opinion on the possible successful issue for this new feature, the idea of which is seductive on account of its numerous intrinsic advantages. It should, nevertheless, for the variable requirements of transport by rail, and in the face of climatic conditions and wind effects, become at least as practical, powerful and economical as the present system.

Another serious competitor to the locomotive for over a quarter of a century has been electric traction, which increases day by day in all countries.

It is worth while recalling that the first practical application of this new method of transport goes back to the small locomotive shown by von Siemens at the Berlin Exhibition (1879), and rapidly spread in America and Europe in the form of installations on urban tramways and modest railways of local interest with light traffic, and almost entirely devoted to passengers. Much praise is due to Italy, which is not in vain the country of Volta, Pacinotti, Galileo Ferraris, in having made the first three trials of electric traction, undertaken on three systems with heavily worked lines (1899-1901). These trials drew the flattering attention of foreign technicians, so much so that at the end of April 1903, 100 English electrical experts, accompanied by the eminent Professor Sylvanus Thompson, went to Lombardy in order to attend and admire the trials that were made. Electric railways rapidly extended everywhere, and already exercise a great influence.

The struggle had commenced, but final comparisons were not yet established so that it could be definitely decided if and how the new system could take the place of the old method of steam

traction, in face of which rose a new rival in the form of the internal combustion engine, an improvement by Diesel (1894) on the primitive Otto cycle (1876) — a prodigious leap which has already given to mankind the new and marvellous mastery which results from automobilism and aviation.

Whatever may happen, however, the steam locomotive has accomplished its hundred years of productive activity, and the English, as mentioned at the beginning of this article, have celebrated the occasion in the best possible way, gathering together objects of interest bearing on the subject.

These have already been described in a very thorough manner by E. L. Ahrons in a series of very complete articles published in *The Engineer*, and entitled *British Locomotives from 1825 to 1924*. This series of articles, which commenced on 2 January 1925, and with the number of 24 April reached with the 17th chapter the year 1859, promises to be a most valuable compilation of retrospective work in this connection.

Italy wished also to be worthily represented at this manifestation, and for this purpose the State Railways on the one hand, and the collaboration of the historico-technical elements and a Committee on the other, with the participation of a large number of railway officials, united together with the object of offering a symbolic escutcheon to express in a significant way their solidarity with the British nation.

As regards this, it is appropriate to call to mind that on previous occasions we have already expressed our staunch admiration for the two Stephensons.

In *La Concordia* newspaper of 17 October 1850, it is stated that as soon as it became known at Turin of the landing of Robert Stephenson (15 October, at 5 p. m., staying at the Trombetta Hotel), the Piedmontese engineers covered with signatures a subscription list to offer a

dinner « to the man of genius who had widened the limits of human power, and honoured old England, his native land, as well as the noble profession in which he had accomplished such admirable work ». Stephenson received the deputation on the morning of the 16th, but declined the invitation on the ground that he had to leave early next morning on urgent business, but arranged to meet his Turin colleagues in the evening, to whom in speaking with admiration of the public achievements of our country, he referred several times to the Ponte Mosca (1830), and the huge system of irrigation which made Piedmont and Lombardy supreme in this respect, and expressed his gratitude for the sympathetic reception accorded to him. He left in fact on the following morning at 6 a. m. for Dusino, — of which we will speak later — and arrived at Genoa on the 19th, where he embarked for Egypt with the object of studying the planning of a canal between the Mediterranean and Red Seas, as stated in the *Corriere Mercantile* of the 19th of the same month.

Robert Stephenson, who had many professional foreign connections, counted amongst them Italy, where he directed the construction of the Leopolda « Livourne-Florence » railway, which was opened to traffic in successive sections from 1844 to 1848. He acquired a great reputation for his talent of discrimination, in addition to his special knowledge of locomotives, as shown in his determined championship of the 4 ft. 8 1/2 in. gauge (1 m. 435) between the inside edges of the rails, now generally adopted, and which is besides a dimension connected with the tradition of the long distant past, since the roadway discovered in the excavation at Pompeii shows that the distance between the wheels of the Roman chariots measured 4 ft. 11 in. In addition, he was a convinced opponent of air power

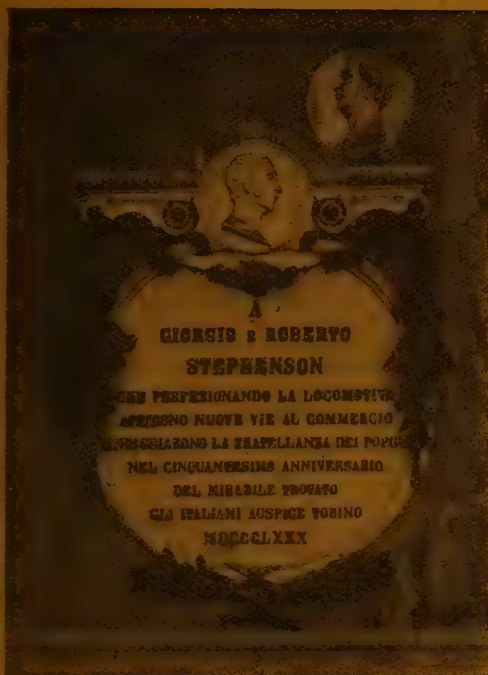


Fig. 3.

railways, and was the inventor of tubular bridges constructed of iron plating, an example of which is the famous Britannia tubular bridge over the Menai Straits, 1 512 feet long and 100 feet above the highest tides, conditions imposed by the Admiralty, and impossible to fulfil by means of an arched bridge. He was also the originator of the method of protecting piles against the pressure of ice, which was applied to the Victoria Bridge at Montreal. For his indefatigable activity he was awarded at his death the greatest honour possible, by being interred (1859) in Westminster Abbey, in the centre of the southern portion of the nave, near the grave of the great explorer, David Livingstone.

On the 19 September 1880, through the efforts of a committee including numerous representatives of workmen's societies, a tablet, reproduced in figure 3, was unveiled at the Porta Nuova Station at Turin, to the sounds of the railway band, which was already in existence, and in the presence of the chief railway authorities, including M. Colnaghi, gen-

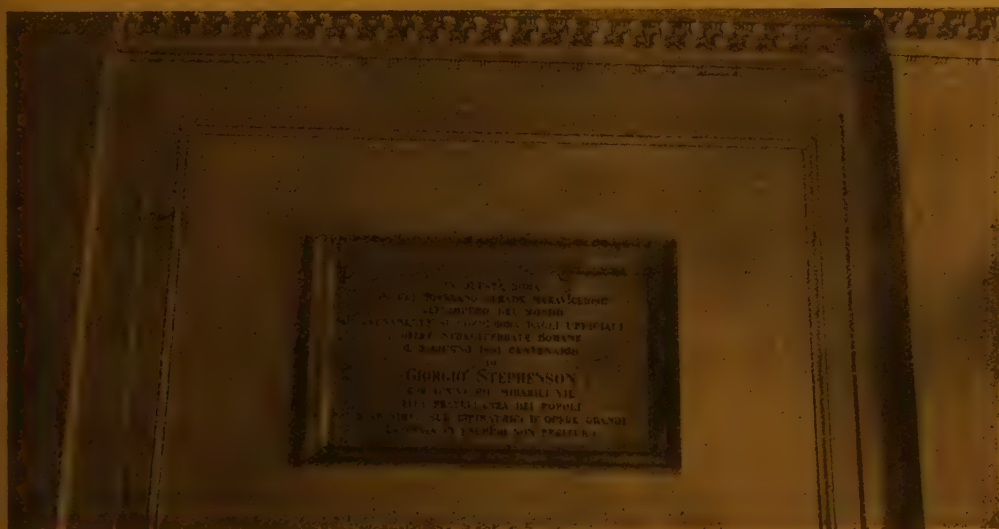


Fig. 4.

eral consul at Florence, specially delegated by the British Government for the ceremony. The official speech (see *Gazzetta del Popolo*, 20 September 1880), was given by Chevalier Benazzo, vice-president of the directorate of the railways of Upper Italy, and a pamphlet commemorative of the lives of George and Robert Stephenson, written by Chevalier M. Elia, founder of the chair of mechanical technology at the Royal Industrial Museum of Turin, was distributed amongst those present.

The only living descendant of the Stephensons, who had collaborated with them all his life, had been invited to this ceremony. This was George Robert Stephenson, who, however, received the invitation too late, but sent a very appreciative letter dated from the « *Columba* » steamship, Greenock, 21 September 1880, and fully reproduced in the *Gazzetta del Popolo* on 2 October following, this date coinciding with the fiftieth anniversary of the Rainhill trials mentioned above.

The marble tablet, with the medallion of George (in the centre), and of Robert, has at the top left-hand corner a bronze design picturing the *Rocket*, and an inscription — placed between the interlaced symbols representing mechanics and thermo-dynamics — the wording of which runs as follows: — « To George and Robert Stephenson, who, by their improvements to the locomotive, opened out new routes for commerce, thus favouring fraternity amongst nations. The Italians, under the auspices of Turin, have on the fiftieth anniversary of this admirable invention, erected this tablet in the year 1880 ».

Finally, the centenary of George Stephenson was also celebrated, a ceremony which took place in Rome at the *Gare centrale* on 9 June 1881, on which occasion a tablet (fig. 4), subscribed for on the initiation of the Roman Railways, was unveiled. The engineer Save-

rio Agazzi, locomotive superintendent, made the official speech which is reported in the *Ingegneria Civile e le Arti Industriali* of Turin No. 6-7 of 1891, p. 110, and contains retrospective remarks of absorbing interest. Amongst other things he foretold the use of continuous automatic brakes, and today it is proved that as far back as 1816, he had noticed the longitudinal sliding or creeping of rails, and suggested the first method of correcting this tendency by means of an embryonic joint of trapezoidal section (1).

And now, since the Italians have so opportunely honoured these two pioneers, and are preparing to do so again this year of 1925, filled with a sentiment of the sincerest admiration, we may be permitted to mention in all justice, a parallel case of merit, though more modest, in the work of three Italian engineers of that period, in the solution of the problem of long gradients as steep as 1 in 28 with sharp curves.

The section from Turin to Moncalieri was opened to traffic on 24 September 1848, with a single-wheel locomotive named *Carlo Alberto*, No. 151, which was built the same year at the Cockerill works, the driving wheels of which were 5 ft. 7 3/8 in. in diameter.

Meanwhile the construction of the line continued towards Genoa, and the service as far as Novi was inaugurated on 1 January 1850, and from Novi to Genoa (crossing the Giovi range), on 18 December 1853.

The section of the line between Vil-

(1) Inscription on the tablet (translated into English): « In this City of Rome, from whence marvellous roads stretched through a world's empire, the centenary of George Stephenson, who by his initiative founded wonderful pathways leading to the brotherhood of nations, and left his inspiring influence in great works as an imperishable example to mankind, is thus worthily commemorated by the officials of the Roman Railways, 9th June 1881. »

lanova and Villafranca d'Asti was not at first laid out as it is at present, now being longer and with easier gradients. Formerly, when leaving Villafranca d'Asti, the line swerved more to the right, crossing its present position at the 23rd mile, and then climbed towards the left straight for Villanova, so that the gradient, which was much shorter (less than 2 miles), was 1 in 40, and during the first 18 months had to be worked by animal traction on the upward slope, whilst in the other direction the speed of the trains had to be regulated by special brake vans. It so happened that Robert Stephenson, on the occasion of the journey mentioned above (1850), was just passing to Dusino, and later on tendered for this section and constructed four tank engines with six coupled wheels (3 ft. 11 5/8 in. diameter) and inside cylinders, the total weight in working order being about 34 tons. These engines were put to work 14 August 1851, where they remained without change until the end of 1858. They were commonly called *mastodons*, and this name in particular, and other facts, are described in the *Atlante di Macchine a Vapore e Ferrovie con leggenda* (Atlas of Steam Engines and Railways with text), by the engineer A. Cavallero, Turin, 1870, on pages 340, 376 and 381. It is easy to show the origin of the name *mastodon*. At the end of September 1849, during the excavations necessitated by the construction of the line, a *mastodon*, or proboscidean mammal of the neocene period and the fore-runner of the elephant, was found. This was described in detail in the *Osteografia di un Mastodonte* by Professor Sismonda, Turin, 1851. Naturally, the discovery had a big effect on the popular imagination, and the unusual name came into common use. Near the locality there still exists a restaurant named the « Restaurant du Mastodonte », and it is probable also that this name was given about the same time to these

metal masses which were the first to climb the steep hillsides.

Later on, the same typical name was used to designate the huge locomotives destined to pull heavy loads up steep gradients, such as the famous *Mastodon* engines of 1898 of the Butte, Anaconda & Pacific Railway, and of the Southern Pacific Railway.

In the American notation this name is reserved for locomotives with ten coupled wheels and a bogie in front (4-10-0).

During the first months of 1852, a scheme was advanced to build a line over the Giovi range between Pontedecimo and Busalla, a section which included a very much longer gradient, much steeper, and with sharper curves. Various firms were asked to tender, amongst others the firms of Sharp & Stephenson, who submitted their proposals.

Three engineers of the Locomotive Department, G. Sommeiller, S. Grandis, and D. Ruva, who were given the task of examining the various offers, chose that of Sharp with suggested improvements, but at the same time they advanced a new friendly solution, which they brought to the notice of the Managing director of railways on 30 June 1852, and presented a table in which « B » represented the new solution, and « A » the improved form of the Sharp engine. The different types are classed in the order of their respective absolute efficiencies.

Engine B	1 320.26
— A	1 072.81
— Sharp	933.12
— Stephenson	678.63

They came to the conclusion that, taking everything into consideration, it would be advisable to build engine « B » because « if on the level adhesion fell to a ninth, it would haul in addition to its own weight, 80 tons ».

This scheme was approved, and the above named engineers prepared a specification in French with drawings complete, and the engines were ordered, three from Cockerill's of Seraing, and three from Stephenson. The latter agreed to make the engines according to the plans received, but declared and stipulated very decisively that he, Stephenson, would not guarantee in any way the success of the tractive effort. As may be seen in the report of 2 March 1854, issued by the Chamber of commerce and agriculture of Turin, who ultimately had to report on the invention, and in which it is said amongst other things that the above mentioned engineers « had achieved a success

which had never been achieved before, either at Semmering or elsewhere ».

In fact the French engineer Flachet was unable to overcome a similar difficulty on the line from Paris to Saint-Germain, and at the Semmering pass, which had two gradients of 1 in 40' (so less steep than that of the Giovi), and on which a special competitive trial had ended unsatisfactorily. Later on Engerth solved the problem by having recourse to the expedient of toothed gearing.

The Italian solution (fig. 5) dated 30 June 1852, was put into service 18 December 1853, and a patent was applied for by the designers under the title « Patent relative to a new arrangement of locomotives suitable for gra-

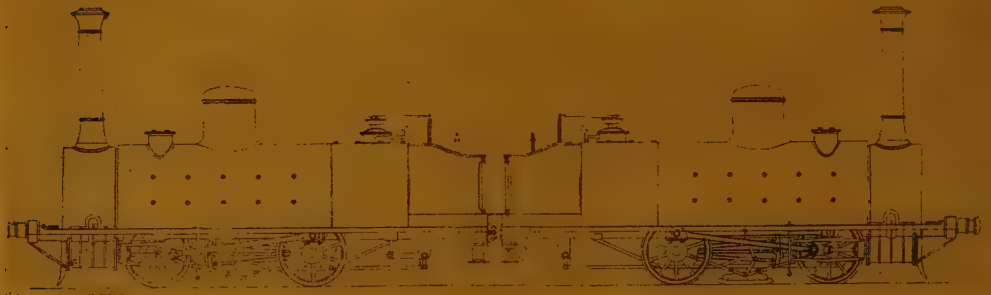


Fig. 5.

dients and curves on railways ». The application was accompanied by three drawings (elevation, section and plan), to a scale of 1/16 with dimensions in English, and entitled « Articulated engines for the gradient of Riccò », this being the name of the torrent running parallel to the line for about three quarters of a mile near Pontedecimo at the foot of the incline. In the patent application, the claim is made as follows: « For the general design and arrangement by which locomotives are built up of two similar units, independent, divisible, of ordinary dimensions,

each unit being carried on four coupled wheels, and connected together by means of a hinged coupling, which allows the combination to run on the sharpest curves with ease; they can be worked by one driver, and by a simple change of wheels may be made suitable for any ordinary gradient, and to obtain the necessary adhesion make complete use of the whole of their weight and that of their coal, water, etc., in order to climb the gradients, and transmit the whole of the tractive effort they are capable of developing. »

On the recommendation of the mem-

bers of the physics and mathematical section of the Royal Academy of Science dated 12 February 1854, and that of the Chamber of agriculture and commerce of Turin, the patent was granted 23 March 1854, for a period of ten years.

The priority of this Italian invention is mentioned by Loria in *Le Strade Ferrate* (The Iron Roads), Vol. 2, p. 148.

It is also described by Fadda in his *Storia dello sviluppo della macchina locomotiva* (History of the Development of the Locomotive Engine), p. 46; and by Cavallero in the above mentioned book of plates; as well as at a lecture

given to the Turin Society of Engineers and Architects, 19 July 1868. The *Rivista Tecnica delle Ferrovie Italiane* of 1 January 1914, also gave an account, and finally the engineer E. Ehrenfreund, at a lecture given at Turin (1922), under the title « Da Newcastle a Torino nel centenario delle Ferrovie », at which the precise wording of the patent was read. The latter is always kept for reference with the original documents at Turin, by the Piedmontese custodians of the archives, 1st section.

However, up to now some confusion appears to have existed, and it is the



Fig. 6.

custom for everybody to call the « Mastodons of the Giovi » those engines with four coupled wheels, which were always defined as the « Giovi double or twin locomotives », and popularly called « Mirimacs ».

It was really only in 1858 that the true *Mastodons* (with six-coupled wheels), described above and built by Stephenson, for Dusino, were transferred to the Giovi incline with others, made afterwards to the same plan, because they had a greater weight in addition to a larger heating surface and were more powerful and at the same time less destructive to the line on account of their better distributed load. Once in service on the Giovi they were also coupled together back to back (fig. 6) according to the Italian method, and kept the name « Mastodons of the Giovi » up to 1861.

About this time some were broken up, and others used as shunting engines at Turin and Alexandria, whilst a small number were kept to assist the heavy trains from Villafranca di Asti to Villanova up till 1873, the year when the locomotives known as « quarte » were put into service. On the other hand, in 1861, a commencement was made on the Giovi line to use engines with four coupled wheels, system Beugnot, which in their turn (1873) were replaced by the « quinte » built by Sigl de Neustadt to the plans furnished by the drawing offices of the Railways of Upper Italy, and which mark a decisive step forward in the history of powerful locomotives. Not satisfied with evolving schemes with their own engine stock, the first Italian railways struck out on lines of their own, such as the famous *Vittorio*

Emanuele locomotive of 1884. This spirit of initiative has always been one of their great merits, and is to their everlasting honour.

The Adriatic system, as well as that of the Mediterranean, followed in the same footsteps, and later on the State Railways built at different periods types which were distinctly successful. This is a fact which His Excellency the Minister Ciano stated in very sympathetic terms in the Chamber of Deputies in the last sittings devoted to the budget of 1925-1926, and this authorised declaration gave a great deal of pleasure to and flattered the just pride of our technicians.

Concerning the first coupled locomotives used on the Giovi incline, we reproduce the following statement made by Cavallero at the above mentioned conference on 19 July 1868: « The Turin to Genoa railway between Busalla and Pontedecimo is made up of very steep gradients and sharp curves, the

former as much as 1 in 28, and extending a length of 1320 feet. In spite of these difficulties we know that this portion of the railway has been worked for a number of years by means of a special class of steam locomotives known as double or twin locomotives of the Giovi incline. These powerful engines, designed by Italian engineers, amongst whom I am pleased to mention and place in the first rank one of the members of our Society, Commandant Germano Sommeiller, consisted of two tank engines which carry their own fuel and water. They were coupled together by means of a hinged coupling, their fireboxes coming back to back. The object of this hinged arrangement is to facilitate the running of the engine round curves of small radius, and the engines being placed back to back make it possible to provide only one foot-plate, enabling them to be worked by one driver assisted by two firemen. The following are the principal particulars :

Weight of the double engine in working order	54 tons.
Diameter of pistons.	14 inches.
Stroke of pistons	22 inches.
Diameter of wheels.	3 ft. 6 in.
Boiler pressure	118 lb. per square inch.
Heating surface, firebox	150 square feet.
Heating surface, tubes.	1400 square feet.
Tank capacity of the two locomotives.	880 English gallons.

The priority of this Italian idea in this special line is further proved by a report of the Academy of sciences attached to a patent taken out by Cortese dated 22 January 1854, which mentions them simply for the sake of reference, stating that twin locomotives had worked regularly on the Giovi incline for over a month, and repeated that « the celebrated engineer Stephenson would take no responsibility as regards their success, limiting himself to building the engines according to the drawings ». This report is also kept in the State archives at Turin.

The twin locomotives of the Giovi incline were fitted also with a brake shoe which could be lowered on to the rails (fig. 5). This was made of iron, 27 1/2 inches long, and fitted with a renewable sole plate. It was fixed between the pairs of wheels and connected up by means of links with spherical joints to the horn blocks. When not in use it was kept at a fixed distance from the ground, and the fireman worked it by means of a shaft with vertical screw and worm wheel and a counter lever, by which it was lowered wedge fashion.

Before concluding this article we

wished to *accentuate the Italian claim of priority for coupling two four wheels coupled locomotives back to back for the purpose of surmounting long, steep and curved gradients*, a system for which we may justly honour the trio of our engineers (Sommeiller, Grandis and Ruva), two of whom have already immortalised themselves by the world known undertaking of the Fréjus, which was the first to break down the race barriers between peoples.

The steam locomotive has therefore, at the end of 100 years of struggle, attained so to say the culminating point of its

possibilities. Thanks to it the double steel belt of the new railways embraces with civilised bonds the most distant countries, making a continuous and rapid pathway over which flows the human flux.

New tasks are also appearing for the modern spirit to deal with, which is always probing into the mysterious and always leaning towards unknown marvels. We confidently predict that the cool calculations of the engineer and the arduous struggles in the workshops will accomplish new victories and lead to new fields of joy and hope!

MISCELLANEOUS INFORMATION.

[621 .535 (.73)]

1. — 250-H. P. petrol-electric motor rail car.

Figs. 1 to 4, p. 569 and 570.

(Engineering.)

The car, which was built by the Westinghouse Electric and Manufacturing Company, of East Pittsburgh, Pa., operates on the Trenton branch of the Reading Company, and makes 21 round trips on weekdays, and 23 on Saturdays, between Trenton and Trenton Junction, which are 3.7 miles apart. The average daily mileage is 170. The branch includes gradients up to 1.1 %, and four station stops are made on each run. On three of the round trips each day, the car hauls a 110 000-lb. trailer coach and also handles the switching of express cars at Trenton and the transfer of a 73-ton express car from Trenton to a main line train at the Junction. The average time for a one-way run between Trenton and Trenton Junction is ten minutes, and with terminal stops the minimum time for a round trip is 24 minutes. The average speed, excluding terminal stops, is 22 miles an hour. The car has replaced two 2-6-4 type locomotives and one coach. The locomotives operated in either direction, and normally ran round the cars at the terminals when changing over. The rail car can operate in either direction, and normally no shunting of any kind is required at the terminals.

The weight of the car ready for the road is 90 000 lb., and the live load is some 10 000 lb. It is 60 feet long over the end sills and 9 ft. 6 in. wide over the posts, the over-all height being 12 ft. 3 1/2 in. The underframe consists of two 12-inch channels with heavy cross-members and is carried on two four-wheel trucks, which have 33-inch wheels at 6 ft. 6 in. centres, and are spaced 44 ft. 6 in. apart. The front truck, which is placed almost directly under the generating set, supports approxima-

tely 60 % of the total car weight. The general arrangement of the car will be easily followed from figures 1 and 2. The body is of steel, and the passenger compartment, which is 35 ft. 10 in. long, has accommodation for 50 people on cross seats. A baggage compartment, 11 feet long by 9 feet wide, is provided. The engine compartment is 10 ft. 8 in. long and contains the 250 H. P. petrol engine and direct-current generator and the necessary control gear.

The engine has six cylinders of 7 1/4-inch diameter and 8-inch stroke, and develops 250-H. P. at 1 100 revolutions per minute. The cylinders have renewable liners and the valves are carried, in the heads, there being two inlet and two exhaust valves for each cylinder. Trunk-type pistons are used with four rings above the gudgeon-pin, and one scraper ring. The crankshaft is carried in seven main bearings, and has a central oil passage which serves for the forced lubrication system. Two complete ignition systems are provided by means of two high-tension magnetos with impulse starters and two independent sets of sparking plugs. The magnetos are driven independently. Fuel supply is by means of vacuum feed from tanks carried under the car. The engine is started by means of two motors, which are connected in parallel across the terminals of a 32-volt battery, one motor alone being capable of starting the engine. A cooling water radiator is fitted at the left side of the car as shown in figure 1, the fan which forces air through the radiator being driven by a motor which is connected across the generator and runs whenever the generator is in operation.



Fig. 1.

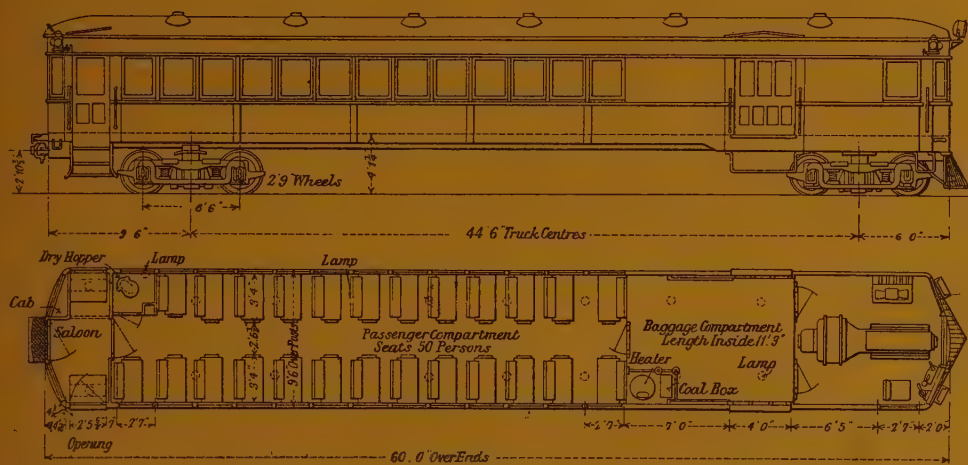


Fig. 2.

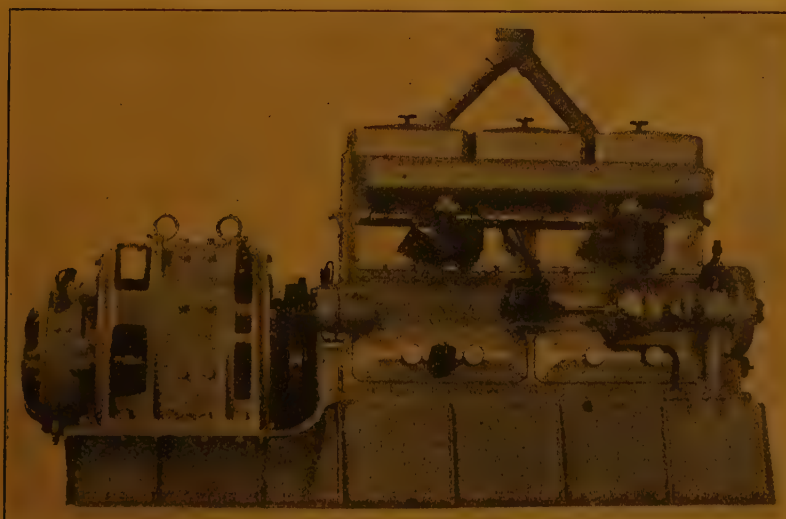


Fig. 3.

The engine and generator, which are shown in figure 3, are carried on a common bedplate mounted on rubber blocks. A flexible coupling is provided between the two machines. The generator is of special type, and has a constant output characteristic which prevents overloading of the engine. The arrangement has proved very satisfactory, and the engine runs at constant speed over a wide range of current output. The normal full-load voltage is 600. The machine is of the six-pole type, and has an exciter mounted directly on its frame, as shown in figure 3. This exciter supplies the main shunt-field winding and also supplies power for car lighting and charging the battery. The shunt field of the exciter is energised from the battery. The constant output characteristic of the main machine has been obtained by means of a differential series winding on the poles of the exciter, through which the main current passes. The arrangement gives variations in field strength proportional to the current demand, so that the voltage drops off correspondingly.

The machine supplies power to two 140-H. P. motors carried on the forward truck of the car. These are of the commutating-pole type, and give good commutation over a wide current range. They drive through 16/61 ratio totally enclosed helical gears. The control apparatus for the car is of a very simple nature, and consists merely of two unit switches for connecting the motors to the generator, and a reverser for changing the direction of flow of current through the motor fields. These appliances are of the electro-pneumatic type, and are operated by a master controller. The car speed varies with the generator voltage. This is regulated by governing the engine speed by operating the throttle. A sequence drum with a cam is carried on the generator with push-rod connections to the throttle. The arrangement is such that the position of the cam determines the throttle setting, and so the engine speed. The movement of the drum is regulated by the same master controller that operates the unit switches and reverser. The driver accordingly has only one control in use for operating the car. The first move-

ment of the master controller closes the unit switches and also a relay that energises the exciter field. Additional movement then causes further rotation of the sequence drum and the opening of the engine throttle. There is a master controller placed at each end of the car to permit operation from either end.

The various auxiliary apparatus include a motor-driven air compressor with a capacity of 20 cubic feet per minute, and two air-storage tanks under the car. These serve for the operation of the air brakes, whistles, bells, sanders and electro-pneumatic switches and reverser. The battery, which has already been referred to, is of 160 ampere-hour capacity. A battery-charging regulator is placed between it and the variable-voltage exciter, while an additional regulator is placed between the battery and all 32-volt circuits.

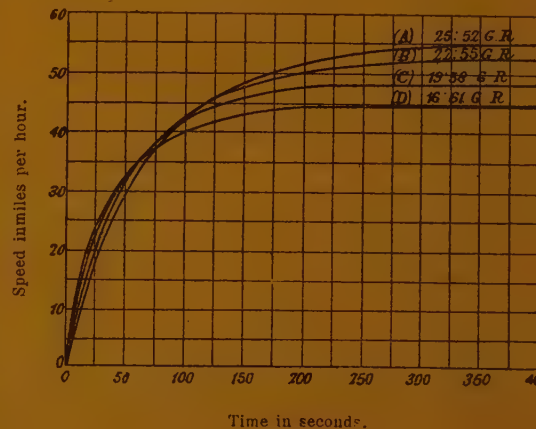


Fig. 4.

The car is capable of speeds up to 51 miles an hour, the maximum speed naturally being determined by the gear ratio. With a smaller reduction than that fitted to the Reading car, a maximum speed up to 55 miles an hour may safely be obtained. Some speed-time curves of cars of this type fitted with different gear ratios are given in figure 4. The curves are for a car fitted as described above and weighing 51 t.

[621. 335 (.73)]

2. — 100-ton oil-electric locomotive.

Figs. 5 and 6, pp. 572 and 573.

(*Railway Mechanical Engineer.*)

A 100-ton oil-electric locomotive built jointly by the Ingersoll-Rand Company, the General Electric Company, and the American Locomotive Company was delivered the latter part of December 1925, to the Long Island for use in freight and switching service. This locomotive was run under its own power, hauling five loaded box cars, one passenger car and a caboose, from Erie, Pa., to Greenville, N. J. Records taken during this run show a consumption of 473 gallons of fuel oil for a total running time of 28 h. 45 m.

The design and construction of the 100-ton locomotive is similar in many respects to the 60-ton oil-electric locomotive built by the same companies and described in the July 1924, issues of the *Railway Mechanical Engineer*. One of these 60-ton locomotives has been in switching service for some time in the Bronx, N. Y., freight terminal yards of the Central Railroad of New Jersey.

The cab of the 100-ton oil-electric locomotive is of all-steel construction and extends the entire length of the locomotive. Its general appearance is similar in many respects to that of an electric locomotive. The width of the cab is 9 ft. 4 in. and the overall length is 40 feet. The overall height of the locomotive, measured from the top of the rail, is 13 ft. 9 1/2 in. The cab is divided into three compartments. The central compartment contains the power plant, oil and water tanks, control equipment and heater. The two end compartments are reserved for the control and operating apparatus. Clear vision for the operator is provided by means of end and side windows. A hatch is provided in the roof of the central compartment directly above the oil engines to permit their removal. A smaller hatch is also provided in the main hatch to facilitate inspection.

The major equipment consists of two 300-H. P., six-cylinder, four-cycle, Ingersoll-

Rand oil engines, operating at 600 revolutions per minute, which are located along each side of the central compartment and midway between the two trucks, and two General Electric, type TDC-6, 200-kw., 600-volt generators, directly connected to the oil engines. The generators are placed at opposite ends of the central compartment in order to secure an even distribution of the load. They supply current to four General Electric, 600-volt railway motors which are geared directly to the axles.

The oil engines.

The oil engines are of the vertical, six-cylinder, four-cycle, single acting, variable speed type having direct fuel oil injection, which is effected by means of two opposed spray nozzles in each combustion chamber. Oil is delivered to the nozzles under pressure by an injection pump driven from the main shaft. Ignition is accomplished by the heat of compression only. One fuel injection pump for each engine serves all six cylinders. Fuel oil distribution is effected by a distributor timed to admit oil successively to the spray nozzles of each cylinder in the proper firing order. The engines are rated for a fuel consumption not to exceed 0.43 lb. per British horse-power at the rated load and speed based on oil containing 19 000 British thermal units per lb. and having a flash point not lower than 150° F. The total capacity of the fuel oil tanks is 400 gallons.

Each engine is equipped with a self-contained, force feed lubricating system. Lubricating oil is pumped to the various moving parts of the engine by a gear-driven pump located in the crank case. Provision is made to filter the oil which comes in contact with the cylinder walls before it is returned to the oil reservoir.

The cylinders, cylinder heads and combustion chambers are completely water-jacketed.

Cooling water is circulated by a centrifugal pump driven from the crank shaft. The temperature of the water in the engine jackets is regulated by a thermostatic valve which controls the circulation of the cooling water from the engines to the radiators on the roof of the cab.

The engines are started by compressed air at approximately 200 lb. pressure, which is admitted to each cylinder in succession through mechanically operated starting valves. Compressed air for starting is provided by a Mianus two-cycle gasoline driven air compressor. Three high pressure air storage tanks are also provided for retaining a supply of compressed air for starting the oil engines.

The electrical equipment.

The generators are 200-kw., 600-volt, direct current, compound-wound, and are separately excited. The voltage is regulated by the current demands of the traction motors so that the product of this current and the voltage is constant for any given engine speed. This makes it possible for the full power capacity of the oil engines to be applied to the drawbar at any speed of the locomotive, and accounts for the relatively large tractive force rating of this type of locomotive.

A 6-kw., 60-volt exciter is mounted on the same shaft with the main generator. A 32-volt, 100-ampere-hour Exide Ironclad storage battery is charged by this exciter in series with one of the field windings. The exciter and storage battery circuit, which is used for lighting and control, is controlled automatically by a switch on the main throttle of the locomotive.

Mounted on each of the four driving axles is a direct current, series motor of the single-gear, box frame, railway type, GE-69-C, manufactured by the General Electric Company. Each motor is supported on its axle by axle brackets and bearings, and by the motor nose which rests on the truck bolster. The gear ratio is 4.375, there being 70 teeth on the gear and 16 teeth on the pinion, both of which are made of forged steel.

The control system.

The speed and stopping and starting of the locomotive is controlled from either end of the cab. There are two control handles. One is a throttle lever which controls the output of the engines and the other is a master controller, or electric switch handle, which connects the traction motors in series or in parallel for either forward or backward movement. No rheostats are used in the power circuit.

In operation, the electric control handle is set for either forward or backward motion, with the motors in series for speeds below five miles per hour, or in parallel for speeds above five miles per hour. This regulation of the speed and tractive force delivered is illustrated by the speed-tractive force curve shown on the chart. The position of the throttle lever

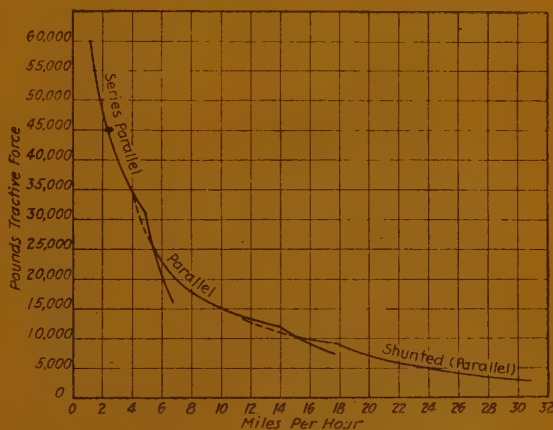


Fig. 6. — Speed-tractive force curve of 100-ton oil-electric locomotive.

determines the power delivered by the engines, which is transmitted by the generators to the motors, automatically adjusting the relation of tractive force and speed to the load on the locomotive and also automatically changing this relation to suit the varying requirements of acceleration or the grade conditions.

Referring to the speed-tractive force curve on the chart, it will be noted that the loco-

motive develops a tractive force of 60 000 lb. at 30 %, the factor of adhesion maintained to approximately one mile per hour. At ten miles per hour the locomotive develops a tractive force of 15 000 lb.

The air brake equipment consists of the Westinghouse, schedule EL-14, straight and automatic air brake. The foundation brake rigging is designed to give a total brake shoe pressure of 60 % of the weight on the drivers with a 50-lb. cylinder pressure. The brake cylinder is 18 inches by 12 inches. An air compressor for providing air for braking is installed in the cab. It has a piston displacement, when working against 130 lb. pressure and at 600 volts, of 100 cubic feet per min. It will deliver air at a pressure of 90 lb. or 140 lb. per square inch.

The running gear consists of two four-wheel, swivel, equalized trucks, each of which is equipped with a cast steel bolster and steel side frames. The side frames are carried on semi-elliptic springs to the equalizers which

are in turn carried on the journal boxes. The journal boxes are of cast steel, pedestal type with A. R. A. bearing and wedge. With the exception of the truck equalizers, axles and that part of the traction motors carried on the axle, the entire weight of the locomotive is spring supported and equally distributed over the four pair of drivers. The axles are of forged open-hearth steel and have 6 1/2-inch by 12-inch journals.

The locomotive is equipped with Leach type D-1 air operated sanders, arranged to sand in front of the leading truck for either direction of operation.

A Peter-Smith water heater and expansion chamber is provided to keep the cooling water from freezing when the engines are not operating and for circulating hot water through the radiators in the operator's compartments. Provision is also made for circulating hot water through the radiators from the circulating system of the oil engines.

*Principal dimensions and proportions of Long Island 100-ton
oil-electric locomotive, No. 401 :*

Builders	General Electric Company ; Ingersoll-Rand Company ; American Locomotive Company.
Type	Oil-electric.
Service	Switching.
Weights on drivers	200 000 lb.
Wheel bases :	
Truck	7 ft. 2 in.
Total locomotive	36 ft. 2 in.
Oil engines :	
Number	2.
Type	Ingersoll-Rand, 6 cylinder, 4 cycle, vertical.
Rated capacity	600 H. P.
Cylinders, diameter and stroke	10 inches by 12 inches.
Speed	600 revolutions per minute.
Piston speed	1 200 feet per minute.
Fuel	Fuel oil.
Generators :	
Number	2.
Type	General Electric, type TDC-6, 200 kw. direct current, 600 revolutions per minute, 600 volt.
Exciter	6 kw., direct connected, 60 volt.
Voltage, variation.	200—750 volts.

Motors :

Number	2.
Type	General Electric, type GE-69-C, 200 H. P., 600 volts.
Capacity of fuel tanks	400 gallons.
Length over couplers	45 ft. 10 in.
Diameter of wheels	36 inches.
Size of journals	6 1/2 inches by 12 inches.
Tractive force.	60 000 lb. at 30 % factor of adhesion main tained at approx. 1 mile per hour.

[621 : 132.5 (.75)]

3. — First Texas type locomotives.

Figs. 7 to 11, pp. 577 and 578.

(*Railway Age*.)

During the month of November 1925, ten locomotives of a new type were delivered to the Texas & Pacific by the Lima Locomotive Works, Inc. These locomotives, which are known as the Texas type, are similar in the principal characteristics of their design to the 2-8-4 type locomotive, known as the *Lima A-1*, which was first placed in service by the builder on the Boston & Albany during the early part of 1925 and which has since received service tests on several other railroads. Both designs include the articulated four-wheel trailing truck carrying a large firebox; both have articulated main rods, and the cylinders in both cases operate at a maximum cut-off of 60 %. The new locomotives, however,

have one more pair of driving wheels, making a 2-10-4 wheel arrangement, which increases the length of the boiler and the tractive force. They also differ from the *Lima A-1* in that they are fitted for oil-burning service.

The new locomotives have a total engine weight of 448 000 lb., of which 300 000 lb. is on the driving wheels. With a boiler pressure of 250 lb. and 60 % cut-off, they develop a tractive force of 83 000 lb., which is increased to 96 000 lb. when the trailer booster is in operation. A comparison of these and other of the principal dimensions, with similar dimensions of the *Lima A-1*, is given in the following table.

Comparison of Texas & Pacific 2-10-4 Locomotives with Lima 2-8-4 Locomotive.

	2-10-4	2-8-4
Cylinders, diameter and stroke, in	29 by 32.	28 by 30.
Cut-off in full gear, per cent	60.	60.
Boiler pressure	250 lb.	240 lb.
Weights in working order :		
On drivers	300 000 lb.	248 000 lb.
Front truck	41 800 lb.	35 500 lb.
Rear truck	106 200 lb.	101 300 lb.
Total engine.	448 000 lb.	385 000 lb.
Diameter of drivers	63 in.	63 in.
Heating surfaces :		
Firebox and combustion chamber	473 sq. ft.	337 sq. ft.
Tubes and flues.	4 640 sq. ft.	4 773 sq. ft.

Total evaporating	5 413 sq. ft.	5 410 sq. ft.
Superheating	2 100 sq. ft.	2 111 sq. ft.
Combined total.	7 213 sq. ft.	7 221 sq. ft.
Grate area	100 sq. ft. (1)	100 sq. ft.
Rated tractive force :		
Engine	83 000 lb.	69 400 lb.
Engine and booster	96 000 lb.	82 600 lb.
Factor of adhesion	3.62.	3.58.

A comparison of the boiler proportions of the two designs is also of interest. While in total evaporating heating surface and superheating surface the new locomotives differ but slightly from the A-1 locomotive, there is a material difference in the distribution of the evaporating heating surface as between the firebox and tubes. The tubes and flues in the new locomotives are 1 ft. 6 in. longer than those in the earlier locomotive, but are fewer in number, accounting for the reduction in the amount of tube and flue heating surface. The firebox, however, including the combustion chamber and the two Nicholson thermic syphons, has a materially larger amount of heating surface, the proportion of firebox heating surface to evaporative heating surface thus being increased from 6.6 % in the *Lima A-1* to 9.26 % in the new locomotives, a difference which, on the basis of Cole's ratios, would account for approximately 10 % more evaporating capacity. The increase in cylinder tractive force from 69 400 lb. to 83 000 lb. amounts to about 19 %. The Texas type locomotives will be assigned to the Ft. Worth and Rio Grande divisions between Marshall, Tex., and Big Springs, a distance of 450 miles. The ruling grades on these divisions approximate 1.5 % and extend from five to eleven miles in length. Heavy curvature is encountered, making necessary the use of the booster in ascending the heaviest portions of these grades.

The boilers of the new locomotives, aside from the increase in length made possible by the increase in the wheel base, differ principally from the boiler of the A-1 locomotive in the inclusion of a 42-inch combustion chamber, in the location of the dome just in front of the combustion chamber, and in the use of an

inside dry pipe. It will be remembered that the dome in the earlier locomotive was located on the front boiler course, with a short outside dry pipe. The dome course in the new boilers is 98 inches in outside diameter, this being reduced by a taper course to 86 1/2 inches at the front course. A shut-off valve, by which the entrance to the dry pipe may be closed, is located in the dome, the operating handle extending out through the right side of the dome. The tubes are 21 ft. 6 in. long and the tube sheets are laid out with 184 flues 3 1/2 inches in diameter, for a Type E superheater of 92 units. With the exception of the change in the dry pipe, the front end arrangement is essentially the same as that of the *Lima A-1*. The unit bolts of the superheater header are accessible through a rectangular opening in the top of the smokebox shell and the Chambers front end throttle is located between the superheater header and the branch pipes forward of the smoke stack.

The firebox, which has the same inside dimensions at the mud ring as the *Lima A-1*, is fitted for oil-burning service, with a 4-inch Booth burner entering the front of the draft pan which is set back about one-third the length of the firebox from the front of the mud ring. The locomotive is designed, however, for possible later conversion to coal-burning service, in which case the two Nicholson thermic syphons (fig. 9) will serve as arch supports.

The locomotives are fitted with an Elesco feedwater heater carried on brackets on the front end. The feedwater pump is located under the running board on the left side of the locomotive.

(1) The firebox is fitted for burning oil.

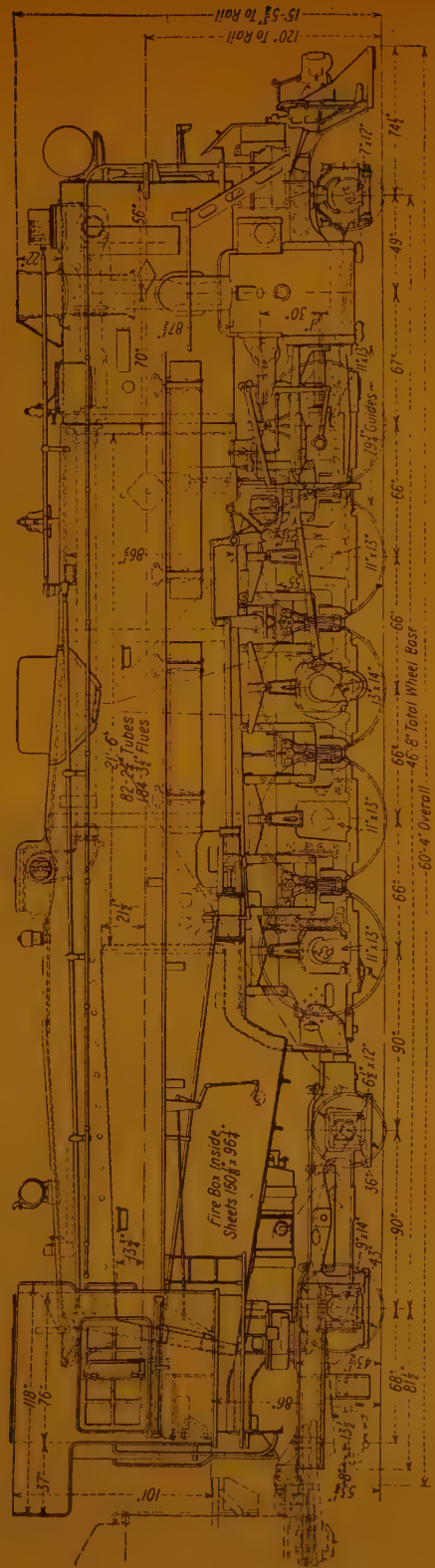




Fig. 9. — Interior of the firebox, showing the position of the Nicholson thermic syphons.



Fig. 10. — The cast steel cylinders showing one of the outside exhaust passages.



Fig. 11. — The articulated trailer frame casting.

The cylinders are 29 inches in diameter by 32 inches stroke. They are steel castings with Hunt-Spiller gun iron bushings and, like the cylinders of the *Lima A-1*, the exhaust steam is carried from extension valve chamber heads through cast pipes which are bolted to openings on the front and back faces of the saddle casting, from whence the exhaust steam is carried inward and upward through cored passages to the exhaust nozzle base at the top of the saddle. These are the only steam passages in the saddle portion of the cylinder castings. The exhaust nozzles are fitted with

tips having the Goodfellow internal projections.

This cylinder construction is shown clearly in figure 10. It has made possible a reduction of the metal sections such that a saving of approximately 4 000 lb. has been made in the weight as compared with equivalent cast iron cylinders.

The valve chamber bushings are fitted with the usual auxiliary starting ports necessary where the locomotive is to operate at a limited maximum cut-off, and in order to effect the maximum attainable smoothness of starting

torque the cut-off at the front end of the cylinder is increased to 63 % at starting and slow speeds by lengthening two of the ports in the front valve chamber bushings. Where the auxiliary starting ports were formerly placed at the bottom of the bushings, they have been moved around to the outside of the bushings in the Texas type locomotives, making them accessible for examination and cleaning by the removal of plugs from the outside walls of the valve chamber. Steam distribution is controlled by Baker valve motion producing a valve travel of 8 3/4 inches, and by the Alco reverse gear.

The frame and running gear designs are the same in principal as those of the 2-8-4 type locomotive. The main frames terminate just back of the rear drivers and between them is bolted a heavy steel hinge casting in which the tongue of the articulated trailing truck is secured by an 8-inch hinge pin. Continuity of the alignment of the main frames and the trailer frame in every respect except lateral turning is secured by the bearing of the top rail of each main frame upon a sliding surface on the hinge extension of the trailer frame, and by supporting the rear end of the firebox directly on the rear end of the trailer frame through combined expansion and lateral motion roller bearings, one on each side of the locomotive. The front end of the firebox is supported from the rear end of the main frames by buckle plates.

The five pairs of drivers are continuously equalized on each side of the locomotive, starting from a fixed point back of each rear driver, and are cross-equalized with the engine truck. Each side of the trailing truck is equalized as a unit. This is the same system of equalization as that of the *Lima A-1*.

The trailer frame of the Texas type locomotives is a one-piece steel casting (fig. 11), the front end of which forms the hinge and in the rear end of which is incorporated the pocket for the Unit drawbar between the engine and tender and on which is mounted the Radial buffer.

The cab is supported on cast steel arms which are bolted to the rear corners of the mud ring and in which are incorporated the

top members of the expansion and lateral motion bearings. The wind sheet extending down from the rear end of the cab deck is divided into two parts so that by the removal of the lower sheet it is possible to run the trailer truck out from under the locomotive without lifting the rear end of the boiler more than enough to relieve the trailer of its load.

The booster, which drives on the rear pair of trailing wheels, is supported from the truck frame by a yoke casting behind the wheels.

The five pairs of drivers are driven by articulated main rods of the type used on the *A-1*, driving on the third and fourth crank pins. Side rods distribute the load from the third pair forward to the second and first, and to the rear from the fourth to the fifth. An interesting feature of the rod arrangement is the setting out of the back side rod pin bearings 3 inches from the face of the wheels, the increased clearance thus provided being used to bring the center of gravity of the counterbalance of the fourth and fifth wheels out nearer to the plane of the reciprocating parts. The forward driving axle is fitted with lateral motion driving boxes designed to provide a total lateral movement of 1 1/2 inches.

The material in the main and side rods is normal carbon-vanadium steel. The piston rods and crank pins are of chrome-vanadium, heat treated, the main crank pins being hollow-bored and the others solid. The piston centers are Carnegie rolled steel fitted with Hunt-Spiller gun iron bull rings and packing rings.

The cylinders receive lubrication from three sources. The principal source is a Nathan Type DV force feed lubricator, the four feeds of which deliver oil to the cylinders and the valve chambers. A Nathan five-feed hydrostatic lubricator is provided for the air pump, the feedwater pump and the booster. The other two feeds are connected to the steam pipes as high above the cylinders as the fittings can be conveniently applied. In addition to these lubricators, a National Graphite Company pendulum type graphite lubricator is fitted in the neck of the superheater header where the saturated steam enters.

The locomotives are served by tenders with a water capacity of 14 000 gallons and a fuel oil capacity of 5 000 gallons. The tender has been designed to permit the application of a stoker with a minimum of alterations should

it later become desirable to convert the locomotives from oil-burning to coal-burning service.

The principal dimensions and proportions of these locomotives are given in the following table :

Railroad	Texas & Pacific.
Type of locomotive	2-10 4.
Service	Freight.
Cylinders, diameter and stroke	29 by 32 in.
Valve gear, type	Baker.
Valves, piston type, size	14 in.
Maximum travel	8 3/4 in.
Steam lap	2 7/16 in.
Exhaust clearance	1/16 in.
Cut-off in full gear	60 %.
Weights in working order	
On drivers	300 000 lb.
On front truck	41 800 lb.
On trailing truck	106 200 lb.
Total engine	448 000 lb.
Tender	275 200 lb.
Wheel bases :	
Driving	22 ft.
Rigid	16 ft. 6 in.
Total engine	46 ft. 8 in.
Total engine and tender	86 ft. 8 in.
Wheels, diameter outside tires :	
Driving	63 in.
Front truck	33 in.
Trailing truck	36 in. and 43 in.
Journals, diameter and length :	
Driving, main	13 in. by 14 in.
Driving, others	11 in. by 13 in.
Front truck	7 in. by 12 in.
Trailing truck	6 1/2 in. by 12 in.
	9 in. by 14 in.
Boiler :	
Type	Taper course.
Steam pressure	250 lb.
Fuel, kind	Oil.
Diameter, first ring outside	86 1/2 in.
Firebox, length and width	150 1/8 in. by 96 1/4 in.
Combustion chamber length	42 in.
Tubes, number and diameter	82—2 1/4 in.
Flues, number and diameter	184—3 1/2 in.
Length over tube sheets	21 ft. 6 in.
Grate area	No grate.

Heating surfaces :

Total evaporative	5 113 sq. ft.
Superheating	2 100 sq. ft.
Comb. evaporative and superheating	7 213 sq. ft.

Tender :

Style	Rectangular.
Water capacity	14 000 gal.
Fuel capacity	5 000 gal.
Rated tractive force	83 000 lb.
Rated tractive force, incl. booster.. . . .	96 000 lb.

NEW BOOKS AND PUBLICATIONS

[628.142.2 (06 (.75)) & 691. (06 (.75))]

Proceedings of the twenty-first annual meeting of the American Wood-Preservers' Association. — One volume (9 × 6 inches) of 385-xlv pages, with numerous tables and plates in the text. — 1925, Democrat Printing Company, Madison, Wisconsin.

This book, which contains 385 pages, is somewhat difficult to review, in that it is in reality a verbatim report of the 21st annual meeting of the American Wood Preservers' Association, and the subjects dealt with are very complex, although dealing chiefly with the treatment and preserving of timbers.

The book shows how thoroughly the American Wood Preservers' Association have gone into this interesting matter of wood preserving. In Great Britain, with which country the reviewer is connected, no preservatives are used for wood for railway carriage construction, unless paint and varnish come under this heading. There are in traffic many coaches which have run 30 years or more, and the timber shows no sign of decay; this is probably due to the result of using only thoroughly well seasoned woods, and under such circumstances there seems to be no necessity for using a preservative on the timber required for railway carriage construction.

In the book under review there is an interesting paper dealing with « Car lumber », and reference is made to an article by Mr. F. S. Shinn, which appeared in the « Railway Mechanical Engineer » of September 1924, in which he gave the probable life of various parts of wooden cars. For stock car decking he gives a life of from 2 to 5 years, and for sills from 5 to 8 years. This compares with a life of naturally seasoned sill pieces in Great Britain of from 15 to 20 years.

In spite of this, Mr. C. Marshall Taylor, in an interesting article on « Wood preservation in Europe », makes the remark that the American railroads can well feel proud of their achievement in this field. It must be said, however, that he chiefly deals with sleepers, etc., with which other papers in the book also discuss.

The book undoubtedly shows the very great consideration which is given to timber for all kinds of purposes in the United States. A. D.

[343. 656.28 (.42)]

RAYNAR WILSON (H.), *Railway Accidents. Legislation and statistics, 1825-1924.* — One volume in-4° (13 × 8 inches) of 39 + xix pages, with two charts and 9 tables in the text. — 1925, The Raynar Wilson Company, 96, Hurlingham Road, London, S. W. 6. — Price : 6 sh.

Mr. H. Raynar Wilson has seized the opportunity presented by the hundredth anniversary of the opening of the first railway over which the public was conveyed by locomotive power to pay a tri-

bute to those who have made railway travel in Great Britain so remarkably safe.

In his « Railway Accidents, Legislation and Statistics : 1825 to 1924 », he

gives a history of British Railway accidents set out in nine tables as under :

- I. — Number and classes of accidents reported, 1851-1924.
- II. — Number and classes of accidents reported 1921-1924.
- III. — Number of passengers and servants killed in accidents to trains, 1850-1924.
- IV. — Class of the 3 280 accidents inquired into, 1871-1908.
- V. — Causes and contributory causes of the 3280 accidents inquired into, 1871-1908.
- VI. — Number and classes of accidents inquired into, 1909-1924.
- VII. — Primary causes of the accidents inquired into, 1919-1924.
- VIII. — Primary causes, as determined by the author, of the 2707 accidents inquired into, 1875-1924.
- IX. — List of all train accidents in which passengers were killed, 1825-1924.

He also presents two charts dealing with :

- I. — Train mileage and number of passengers, 1875-1924.
- II. — Number of route-miles; train-miles per route-mile; tonnage per route-mile, 1875-1913.

In chapter I — « The Purpose of the Work » — the author gives his views on the subject of railway accidents and expresses the opinion, contrary to that which very widely prevails, that a large proportion of mishaps have been due to causes for which the men could not be held responsible.

Tribute is paid to the good work done by British railwaymen, both present and past, and to the men — whose names are now almost forgotten — who in early railway history designed, introduced, and improved numerous safeguards against the then insecurity of railway travel.

Chapter II — « Legislation ». — The author sets out very clearly and fully the legislation designed to reduce accidents and promote greater safety both to the workers and the users of the railway.

The regulation of Railways act of 1840 gave the Board of Trade certain authority over the railways. The general principle of this legislation has not since been repealed.

On January 25th 1841, the Railway Department made its first report to the Board of Trade and stressed the inadequacy of the powers given to that Board having regard to the public safety.

By the Act of 1842 the railway companies were required to render returns of all serious accidents whether attended with personal injury or not.

December 4th 1857, saw the appointment of a select committee to inquire into the causes of accidents on railways and the possibility of removing any such causes by further legislation. The question of additional powers for the Board of Trade again became the subject of discussion and the provision of communication between passengers and the servants in charge of the train was urged. An Act passed in 1868 ordered that every train which carried passengers and travelled more than 20 miles without stopping was to be provided with efficient means of communication.

The act of 1871, which was an important step taken in the cause of safety on railways, put the procedure to be followed for railway accidents on a proper basis, the accidents to be reported were enlarged and more definitely stated, and the holding of enquiries was legalised.

One consequence of the act of 1871 was the introduction of the series of Board of Trade annual reports, the first of which was for the year 1870, and these reports continue to this day.

The Regulation of railways act of 1889 made compulsory the block system, concentration and interlocking on passenger lines and the provision of au-

tomatic continuous brakes on passenger trains.

The Railway employment (prevention of accidents) Act of 1900, although applying to railway servants, gave very great power to the Board of Trade in the matter of accidents generally.

In 1919 the powers as to railways possessed by the Board of Trade were transferred to the Ministry of Transport on the constitution of the latter in that year.

Chapter III — « The Tables Explained » — gives detailed explanations of the nine tables referred to above and cannot fail to be of great assistance and interest

to laymen and others who desire to appreciate the work that has been done to make railway travel a very low risk.

As an illustration of what has been accomplished in the manufacture of the parts of rolling stock, it is interesting to note that in the five years 1871-1875 inclusive there were 1 048 axle failures as compared with 325 for the period 1921-1924. There are no figures available to show the number of axles in use in the two periods, but when it is remembered that the train miles in the latter period were twice as many as the former the improvement is remarkable.
